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PREFACE

There are branches of knowledge which we believe may be better acquired from a silent teacher in a pleasing book than in any more formal way. John Knox was of opinion that there ought to be a school in every parish, a grammar-school in every borough, a college in every city; so, we would add, there ought to be a "Home Tutor" in every family. A book can be listened to or not, at will. Its instructions are not forced; therefore, they are the more agreeable: it makes no one pedantic—for pedantry is a fungus of the school desk, where an exaggerated importance is apt to be given to small portions of attainment, while treatises such as this volume contains, both comprehensive and broad of view, convey no flattering impressions to self-importance, but suggest rather that humility which the wise Newton expressed in presence of the great ocean of truth.

It is not too much to say that the present times demand from every intelligent member of society an acquaintance with the leading facts, at least, of the subjects of study presented to the reader in this Volume. A great deal of social science, and therefore of social happiness, is connected with the truths of Natural Philosophy and the Physical History of Mankind. They know but little indeed of God's great works in animated nature who are ignorant of Zoology. Who can rightly appreciate the past that cannot read in the great earth-tablets of Geology the growth and development of the world we live in? Who can form any enlarged notions of the existing frame of nature, whose eyes are not opened to the wonders of Celestial and Terrestrial Phenomena?

These important subjects are, in the following pages, treated with a view to the principle enunciated by Pope—

> "Men must be taught as if you taught them not,
> And things unknown proposed as things forgot."

We have striven to interest the affections, the sentiments, and the imagination with Nature's living facts, which are in themselves more full of entertainment than all the fictions that fancy ever devised. Indeed, we think it is something, at the present day, to offer a solid counter-charm to that ephemeral literature over which so many young persons waste their brief leisure—a leisure that, rightly turned to account, with the help of our "HOME TUTOR," would render them more fit for the serious business of life.

Writers of the highest eminence in the different departments of knowledge treated in this Book have laboured to render each subject attractive, without sacrificing that solid character which sound Knowledge, to be of any value, must ever present to the thoughtful intellect. They have endeavoured to meet the wants of parents in the ordinary duties of Home Education—to excite a love of information in the uninformed—to supply the needs of partially educated students—and to provide a Volume which can be conscientiously recommended to all who aim at self-culture, and seek to attain it with the smallest possible expenditure of time and mental labour.

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PART I.

NATURAL PHILOSOPHY.

NATURAL PHILOSOPHY:

BY PROFESSOR DRAPER.

INTRODUCTION.

THE main object of a teacher should be to communicate a clear and general view of the great features of his science, and to do this in an agreeable and short manner. It is too often forgotten that the beginner knows nothing; and the first thing to be done is to awaken in him an interest in the study, and to present to him a view of the scientific relations of those natural objects with which he is most familiar. When his curiosity is aroused, he will readily go through things that are abstract and forbidding; which, had they been presented at first, would have discouraged or perhaps disgusted him.

I am persuaded that the superficial knowledge of the physical sciences which so extensively prevails is, in the main, due to the course commonly pursued by teachers. The theory of Forces and of Equilibrium, the laws and phenomena of Motion, are not things likely to allure a beginner; but there is no one so dull as to fail being interested with the wonderful effects of the weight, the pressure, or the elasticity of the air. It may be more consistent with a rigorous course to present the sterner features of science first; but the object of instruction is more certainly attained by offering the agreeable.

There are two different methods in which Natual Philosophy is taught:—1st, As an experimental science; 2nd, As a branch of mathematics. Each has its own peculiar advantages; and the public teacher will follow the one or the other, according as it is his aim to store the mind of his pupil with a knowledge of the great facts of Nature, or only to give it that drilling which arises from geometrical pursuits. From an extensive comparison of the advantages of these systems, I believe that the proper course is to teach physical science experimentally first—a conviction not only arising from considerations respecting the constitution of the human mind, the amount of mathematical knowledge which students commonly possess, but also from the history of these sciences. Why is it that the most acute mathematicians and metaphysicians the world has ever produced for two thousand years made so little advance in knowledge? and why have the last two centuries produced such a wonderful revolution in human affairs? It is from the lesson first taught by Lord Bacon, that, so liable to fallacy are the operations of the intellect, experiment must always be the great engine of human discovery,—and, therefore, of human advancement.

JOHN WILLIAM DRAPER.

* The sections throughout this Treatise with brackets are by the Editor.

NATURAL PHILOSOPHY.—ELEMENTARY PRINCIPLES.

CHAPTER I.

PROPERTIES OF MATTER.—*The Three Forms of Matter—Vapours—The distinctive, essential, and accessory properties—Extension—Impenetrability—Unchangeability—Illustrations of Extension—Methods of measuring small spaces—The Spherometer—Illustration of Impenetrability—The Diving Bell—The accessory properties of Matter—Compressibility—Expansibility—Elasticity—Limit of Elasticity—Illustrations of Divisibility—Porosity and interstitial spaces—Weight.*

MATERIAL substances present themselves to us under three different conditions. Some have their parts so strongly attached to each other that they resist the intrusion of external bodies, and can retain any shape that may be given them. These constitute the group of SOLIDS. A second class yields readily to pressure or movement, their particles easily sliding over one another; and from this extreme mobility they are unable of themselves to assume determinate forms, but always copy the shape of the receptacles or vessels in which they are placed—they are LIQUIDS. A third, yielding even more easily than the foregoing, thin and aërial in their character, and marked by the facility with which they may be compressed into smaller or dilated into larger dimensions, give us a group designated as GASES. Metals may be taken as examples of the first; water as the type of the second; and atmospheric air of the third of these states or conditions, which are called "the THREE FORMS of bodies."

In some instances the same substance can exhibit all three of these forms. Thus, when liquid water is cooled to a certain degree, it takes on the solid condition, as ice or snow; and when its temperature is sufficiently raised, it assumes the gaseous state, and is then known as steam. Writers on Natural Philosophy have found it convenient, for many reasons, to introduce the term *Vapours*, meaning by that a gas placed under such circumstances that it is ready to assume the liquid state. As the steam of water conforms to this condition, it is therefore regarded as a vapour.

Under whichever of these forms material substances are presented, they exhibit certain properties—these are, first, Distinctive; second, Essential; third, Accessory.

There is a certain bright white metal passing under the name of Potassium, the *distinctive* character of which is, that, when thrown on the surface of water, it gives rise to a violent reaction, a beautiful violet-coloured flame being evolved. A piece of lead, which to external appearance is not unlike the potassium, when brought in contact with water exhibits no such phenomenon, but, as every one knows, remains quietly, neither disturbing the water nor being acted upon by it.

Fig. 1.

Such distinctive qualities are the objects of a chemist's studies. It belongs to his science to show how some gases are coloured and others colourless; some supporters of combustion, while others extinguish burning bodies; how some liquids can be decomposed by voltaic batteries and some by exposure to a red heat. The general doctrines of affinity, the modes in which

bodies combine, and the characters of the products to which they give rise —all these belong to Chemistry.

But beyond these distinctive qualities of bodies, there are, as has been observed, certain other properties which are uniformly met with in all bodies whatever, and hence are spoken of as ESSENTIAL. They are,

Extension.
Impenetrability.
Unchangeability.

By EXTENSION we mean that all substances, whatever their volume or figure may be, occupy a determinate portion of space. We measure them by three dimensions—length, breadth, and thickness.

IMPENETRABILITY points out the fact that two bodies cannot occupy the same space at the same time. If a nail is driven into wood, it enters only by separating the woody particles from each other; if it be dropped into water, it does not penetrate, but displaces the watery particles: and even in the case of aërial bodies, through which masses can move with apparently little resistance, the same observation holds good. Thus, if we take a wide-mouthed bottle, *a*, Fig. 2, and insert through its cork a funnel, *b*, with a narrow neck, and also a bent tube, *c*, which dips into a glass of water, *d*, on pouring any liquid into the funnel, so that it may fall, drop by drop, into the bottle, we shall find, as this takes place, that air passes out, bubble after bubble, through the water in *d*. The air is, therefore, not penetrated by the water, but displaced.

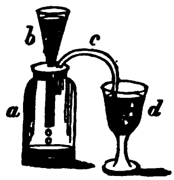

Fig. 2.

The same fact may also be proved by taking a cupping-glass, *a*. Fig. 3, and immersing it, mouth downwards, in a glass of water, *b*. If the aperture, *c*, of the cupping-glass be left open, the air will rush out through it, and flow in below: but if it be closed by the finger, as the air can now no longer escape, the water is unable to enter and occupy its place.

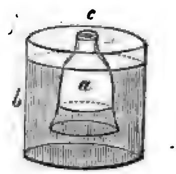

Fig. 3.

Similar experiments establish the impenetrability of liquids by solids. If in a glass of water, Fig. 4, a leaden bullet is immersed, it will be seen that as the bullet is introduced the water rises to a higher level, showing, therefore, that a liquid can no more be penetrated by a solid than, as was seen in the former experiment, can a gas by a liquid. Two bodies cannot occupy the same space at the same time.

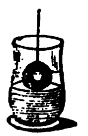
Fig. 4.

The third essential property of matter is its UNCHANGEABILITY. This property may be looked upon as the foundation of Chemistry; and though there are many phenomena which we constantly witness which seem to contradict it, they form, when properly considered, striking illustrations of the great truth that material substances can neither be created nor destroyed; and that the distinctive qualities which appertain to them remain for ever unchanged. The disappearance of oil in the combustion of lamps, the burning away of coal, the evaporation of water, when minutely examined, far from proving the perishability of matter, afford the most striking evidence of its duration. Nor is a solitary fact known in

the whole range of Chemistry, Natural Philosophy, or Physiology, which lends the remotest countenance to the opinion that, either by slow lapse of time or by any artificial processes whatever, can matter be created, changed, or destroyed. Even the bodies of men and animals, the structures of plants, and all other objects in the world of organization, which seem characterized by the facility with which they undergo, unceasing and, eventually, total change, are no exceptions to the truth of this observation. The bodies which we possess to-day are made up of particles which have formed the bodies of other animals in former times, and which will again discharge the same duty for races that will hereafter come into existence.

As illustrations connected with the extension and impenetrability of matter, I may give the following instances:

We are frequently required to measure the dimensions of bodies; that is, to determine their length, breadth, or thickness. It is a much more difficult thing to do this accurately than is commonly supposed. It requires an artist of the highest skill to make a measure which is a foot or a yard in length, or which shall contain precisely a pint or a gallon. With a view of facilitating the measurement of bodies, a great many contrivances have been invented, such as verniers, spherometers, and screw machines of different kinds.

The spherometer, which is a beautiful contrivance for measuring the thickness of bodies, is constructed as follows: It has three horizontal steel branches, *a*, *b*, *c*, Fig. 5, which form with each other angles of 120 degrees. From the extremities of these branches there proceed three delicate steel feet, *d*, *e*, *f*, and through the centre, where the branches unite, a screw, *g*, the thread of which is cut with great precision, and which terminates in a pointed foot, *i*, passes. The head of this screw carries a divided circle, *m*. Now, suppose the instrument is placed on a piece of flat glass, it will be supported on its three feet, which are all in the same plane; but if in turning the screw we depress its point, *i*, beneath the plane of its feet, it can no longer stand with stability on the glass, but totters when it is touched, and emits a rattling sound. By altering the screw, therefore, we can give it such a position that both by the finger and the ear we discover that its point is level with the points *d*, *e*, *f*. Now let the object, the thickness of which is to be measured, be placed on the glass, and the screw turned until the instrument stands without tottering; it is obvious that its point must have been lifted through a distance precisely equal to the thickness of the object to be measured, and the movement of the head of the screw, read off upon the scale *n*, against which it works, indicates what that thickness is.

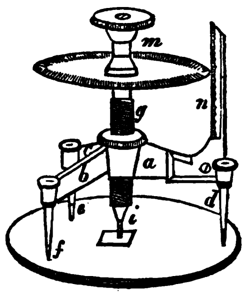

Fig. 5.

This instrument, therefore, serves to show that in the measurement of small spaces, the senses of touch and hearing may often be resorted to with more effect than the eye. The spherometer is here introduced in connection with these general considerations respecting the extension of matter, as affording the student an illustration of the delicate methods we possess of determining the minutest dimensions of bodies.

As an illustration of the impenetrability of matter, the machine which passes under the name of the diving-bell may be mentioned. It consists of a vessel, *a a*, Fig. 6, of any suitable shape, and heavy enough to sink in water when plunged with its mouth downward. Owing to the impenetrability of the air, the water is excluded from the interior, or only finds access to such an extent as corresponds to the pressure of the depth to which it is sunk. Light is admitted to the bell through thick pieces of glass in its top, and a constant stream of fresh air thrown into it from a tube, *b*, and forcing-pump above, the atmosphere in the inside being suffered to escape through a stop-cock as it becomes vitiated by the respiration of the workmen. Diving-bells are extensively resorted to in submarine architecture, and for the recovery of treasure lost in the sea.

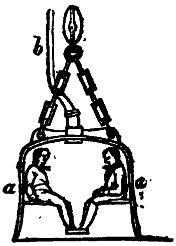

Fig. 6.

Having disposed of the *essential*, we pass next to a consideration of the *accessory properties* of matter. They are,—

Compressibility.	Expansibility.	Elasticity.
Divisibility.	Porosity.	Weight.

That substances of all the three forms are compressible is capable of easy proof. In the process of coining, pieces of metal are exposed to powerful pressure between the steel dies, so that they become much denser than before. By enclosing water or any other liquid in a strong vessel, and causing a pison, driven by a screw, to act upon it, it may be reduced to a less space; and gaseous substances, such as atmospheric air, when enclosed in an india-rubber bag, or even a bladder, may be compressed by the hands.

Under the influence of heat all substances expand. This may be proved for such solids as metals, by the apparatus represented in Fig. 7. It consists of a stout board, *a*, *b*, on which are fastened two brass uprights, *c*, *d*, with notches cut in them, so as to receive the ends of a metallic bar, *e*. This bar is slightly shorter than the whole distance between the notches, so that when it is set in its place, it can be moved backward and forward, and emits a rattling sound. But if boiling water be poured upon it, it expands and occupies the whole distance, and can no longer be moved.

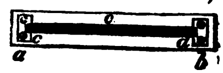

Fig. 7.

[A very simple manner of illustrating the expansion of metals by heat is showing the following diagram. A plate of brass or other metal is made of the same shape as the upper one in the above figure, and a rod of metal—the same kind as the plate—is fixed to a metal stem inserted in a wooden handle, as *d c*. The rod is made to fit the hole *b*, and also the space *a*, between the two ends. When the metallic rod is plunged into hot water, or heated over the flame of a spirit-lamp, the expansion is so great that it becomes impossible to pass the end of the rod through the hole *b* or the space *a*.

Fig. 8.

The expansion of liquids is well shown in the case of common thermometers, which contain either quicksilver or spirits of wine, those sub-

stances occupying a greater volume as their temperature rises. The air-thermometer proves the same thing for gases.

By elasticity we mean that quality by which bodies, when their form has been changed, endeavour to recover their original shape. In this respect there are great differences. Steel, ivory, india-rubber, are highly elastic; lead, putty, and clay, less so. Perfectly elastic bodies resist the action of disturbing causes without any ulterior change; thus, a quantity of atmospheric air, compressed into a copper globe, recovers its original volume as soon as the pressure is removed, though it may have been shut up for years. By the *limit of elasticity* we mean the smallest force which is required to produce a permanent disturbance in the structure of an imperfectly elastic body. No solid is perfectly elastic. An iron wire, drawn a little aside, recovers its original straightness; but if more violently bent, it takes a permanent set, because its limit of elasticity is overpassed. The elasticity of a given substance can often be altered by mechanical processes, such as by hammering, or by heating and cooling, as in the process of tempering.

The divisibility of matter may be proved in many ways. By various mechanical processes, metals may often be reduced to an extreme degree of tenuity; thus it is said, that gold-leaf may be beaten out until it is only $\frac{1}{300000}$ of an inch thick. By chemical experiments, a grain of copper or of iron may be divided into many millions of parts. For certain purposes artists have ruled parallel lines upon glass, with a diamond point, so close to each other, that ten thousand are contained in a single inch. The odours which are exhaled by strong-smelling perfumes, as musk, will for years together infect the air of a large room, and yet the loss of weight by the musk is imperceptible. Again, there are animals whose bodies are so minute, that they can only be seen by the aid of the microscope. The siliceous cells of such infusorials occur in many parts of the earth as fossils. Ehrenberg has shown that tripoli, a mineral used in the arts, is made up of these—a single cubic inch of it containing about forty-one thousand millions—that is, about fifty times as many individuals as there are of human beings on the face of the globe.

As substances of all kinds may be reduced to smaller dimensions, either by pressure or the influence of cold, and as it is impossible for two particles to occupy the same place at the same time, or even for one of them partially to encroach on the position occupied by the other, it necessarily follows that there must be pores or interstices even in the densest bodies.

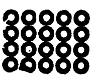

Fig. 9.

[The annexed diagram will illustrate the interstitial spaces between the atoms of bodies, and this may be further demonstrated by the following simple experiment: Place marbles in a jar until it will not hold any more, and you will find that there are spaces between the marbles, because you may afterwards add shot and sand, and finally water.]

Thus quicksilver will readily soak into the pores of gold, and gases ooze through india-rubber. Writers on Natural Philosophy usually restrict the term "pore" to spaces which are visible to the eye, and designate those minute distances which separate the ultimate particles of bodies by the term "interstices."

All bodies have weight or gravity. It is this which causes them to fall, when unsupported, to the ground; or when supported, to exert pressure

upon the supporting body. Nor is this property limited to terrestrial objects; for in the same way that an apple tends to fall to the earth, so too does the moon; and all the planets gravitate toward each other and toward the sun. It was the consideration of this principle that led M. Leverrier to the discovery of a new planet beyond Uranus—this latter star being evidently disturbed in its movements by the influences of a more distant body hitherto unknown.

CHAPTER II.

PHYSICAL FORCES.

Attractive and Repulsive Forces—Molecular Attraction—Gravitation—Cohesion—Constitution of Matter.

ALL changes taking place in the system of nature are due to the operation of forces. The attractive force of the earth causes bodies to fall, and a similar agency gives rise to the shrinking of substances—their parts coming closer together when they are exposed to the action of cold. In like manner, when an ivory ball is suffered to drop on a marble slab, its particles, which have been driven closer to one another by the force of the blow, instantly recover their original positions by repelling one another; that is to say, through the agency of a repulsive force. Of the nature of forces we know nothing. Their existence only is inferred from the effects they produce; and according to the nature of those effects, we divide them into ATTRACTIVE and REPULSIVE FORCES—the former tending to bring bodies closer together, the latter to remove them further apart.

It has been found convenient to divide attractive forces into three groups, according as the range of their action or the circumstances of their development differ. When the attractive influence extends only to a limited space, it is spoken of as *molecular attraction;* but the attraction of gravitation is felt throughout the regions of space. By cohesion is meant an attractive influence called into existence when bodies are brought to touch one another. It is to be understood that these are only conventional distinctions; and it is not improbable that all the phenomena of attraction are due to the agency of one common cause.

Chemists have shown that, in all probability, material substances are constituted upon one common type. They are made up of minute, indivisible particles, called atoms, which are arranged at variable distances from each other. These distances are determined by the relative prevalence of attractive and repulsive forces, resident in or among the particles themselves; and so too is the form of the resulting mass. If the cohesive predominates over the repulsive force, a solid body is the result; if the two are equal, it is a liquid; and if the repulsive prevails, it is a gas.

There are many reasons which lead us to suppose that the repulsive force, which thus tends to keep the particles of matter asunder, is the agent otherwise known as heat. Whenever the temperature of a body rises, it enlarges in volume, because its constituent particles move from each other, and on the temperature falling, the reverse effect ensues. If, as many very eminent

philosophers believe, heat and light are in reality the same agent, it follows, by a necessary consequence, as will be gathered from what we shall hereafter have to say on optics, that the atoms of bodies vibrate unceasingly, and that instead of there being that perfect acquiescence among them which a superficial examination suggests, all material substances are the seat of oscillatory movements, many millions of which are executed in the space of a single second of time: the number increasing as the temperature rises, and diminishing as it falls.

CHAPTER III.

OBSERVATIONS ON NATURAL PHILOSOPHY.

PNEUMATICS.—*General Relations of the Air—Its connection with Motion and Organization—Limited Extent—Constitution—Compressibility—Causes which Limit the Atmosphere—Its Variable Densities—Proportionality of its Elastic Force and Pressure.*

A VERY superficial knowledge of those parts of the world to which man has access, readily leads to their classificaton under three separate heads—the Air, the Sea, and the solid Earth. This was recognised in the infancy of science; for the four elements of antiquity were the divisions which we have mentioned, and Fire.

NATURAL PHILOSOPHY OF PHYSICAL SCIENCE, which, in its extended acceptation, means the study of all the phenomena of the material world, may commence its investigations with any objects or any facts whatever. By pursuing these, in their consequences and connections, all the discoveries which the human mind has made in this department of knowledge might successively be brought forward. But when we are left to select at pleasure our point of commencement, it is best to follow the most natural and obvious course. All the advances made in our times by the most eminent philosophers, and our powers of appreciating and understanding them, depend on clearness of perception of the great fundamental facts of science—a perspicuity which can never arise from mere abstract reasonings or from the unaided operations of the human intellect, but which is the natural consequence of a familiarity with *absolute facts.* These serve us as our points of departure, and in the more difficult regions of science they are our points of reference—often by their resemblances, and even by their differences, making plain what would otherwise be incomprehensible, and spreading a light over what would otherwise be obscure.

In the three divisions of material objects, which are so strikingly marked out for us by Nature, we find traits that are eminently characteristic. All our ideas of permanence and duration have a convenient representation in the solid crust of the earth, the mountains, and valleys, and shores of which retain their position and features unaltered for centuries together. But the air is the very type and emblem of variety, and the direct or indirect source of almost every motion we see. It scarce ever presents to us, twice in succession, the same appearance; for the winds that are continually traversing it are, to a proverb, inconstant, and the clouds that float in it exhibit every

possible colour and shape. It is, in reality, the grand origin or seat of all kinds of terrestrial motions. Storms in the sea are the consequences of storms in the air, and even the flowing of rivers is the result of changes that have transpired in the atmosphere.

But the interest connected with it is far from ending here. The atmosphere is the birthplace of all those numberless tribes of creation which constitute the vegetable and animal world. It is of materials obtained from it that plants form their different structures, and therefore from it that all animals indirectly derive their food. It is the nourisher and supporter of life, and in those processes of decay which are continually taking place during the existence of all animals, and which after death totally resolve their bodies into other forms, the air receives the products of those putrefactive changes, and stores them up for future use. And it is one of the most splendid discoveries of our times, that these very products which arise from the destruction of animals are those which are used to support the life and develop the parts of plants. They pass, therefore, in a continual circle—now belonging to the vegetable, and now to the animal world; they come from the air, and to it they again are restored.

It is not, therefore, the beautiful blue colour which the air possesses, and which people commonly call the sky, or the points of light which seem to be in it at night, or the moving clouds which overshadow it and give it such varied and fantastic appearances, or even those more imposing relations which bring it in connection with the events of life and death, which alone invest it with a peculiar claim on the attention of the student. Connected as it is with the commonest of every-day facts, it furnishes us with some of our most appropriate illustrations—those simple facts of reference of which I have already spoken, and to which we involuntarily turn when we come to investigate the more difficult natural phenomena.

Astronomical considerations show that the atmosphere does not extend to an indefinite region, but surrounds the earth on all sides to an altitude of about fifty miles. Compared with the mass of the earth its volume is quite insignificant; for as it is nearly four thousand miles from the surface to the centre of the earth, the whole depth of the atmosphere is only about one-eightieth part of that distance. Upon a twelve-inch globe, if we were to place a representation of the atmosphere, it would have to be less than the tenth of an inch thick.

Seen in small masses, atmospheric air is quite colourless and perfectly transparent. Compared with water and solid substances, it is very light. Its parts move among one another with the utmost facility. Chemists have proved that it is not, as the ancients supposed, an elementary body, but a mixture of many other substances. It is enough at present for us to know that its leading constituents are two gases, which exist in it in fixed quantities—they are oxygen and nitrogen—but other essential ingredients are present in a less proportion, such as carbonic acid gas, and the vapour of water.

Atmospheric air is taken by natural philosophers as the type of all gaseous bodies, because it possesses their general properties in the utmost perfection. Individual gases have their special peculiarities—some, for example, are yellow, some green, some purple, and some red.

The first striking property of atmospheric air which we encounter, is the facility with which the volume of a given quantity of it can be changed. It

is highly compressible, and perfectly elastic. A quantity of it tied tightly up in a bladder or india-rubber bag, is easily forced by the pressure of the hand into a less space. The material properties of the air, and its compressibility, are simultaneously illustrated by the experiment of the diving-bell, described under Fig. 6. A vessel forced with its mouth downward under water, permits the water to enter a little way, because the air contained in the vessel occupies less space under the pressure; but as soon as the vessel is again brought to the surface of the water, the air within it expands to its original bulk.

This ready compressibility and expansibility may be shown in many other ways. Thus, if we take a glass tube, Fig. 10, with a bulb, *b*, at its upper end, the lower end being open and dipping into a vessel of water, *c*, and having previously partially filled the tube with water to the height, *a*, it will be found, on touching the bulb with snow, or by pouring on it ether, or by cooling it in any manner, that the included air collapses into a less bulk. It is, therefore, compressible, and on warming the bulb with the palm of the hand, the air is at once dilated.

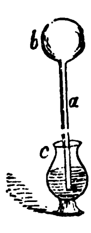

Fig. 10.

It is this quality of easy expansibility and compressibility which distinguishes all gaseous substances from solids and liquids. It is true the same property exists in them, but then it is to a far less degree. On the hypothesis that material bodies are formed of particles which do not touch one another, but are maintained by attractive and repulsive forces at determinate distances, it would appear that, in a gas like atmospheric air, the repulsive quality predominates over the attractive; while in solids the attractive force is the most powerful, and in liquids the two are counterbalanced.

Again, as respects relative weight, the gases, as a tribe, are by far the lightest of bodies; and, indeed, it is among them that we find the lightest substance in Nature—hydrogen gas. They are, moreover, the only *perfectly elastic* substances that we know. Thus a quantity of atmospheric air compressed into a metal reservoir will regain its original volume the moment it has the opportunity, no matter how great may be the space of time since it was first shut up.

Under a relaxation of pressure this perfect elasticity displays itself in producing the expansion of gas. If a bladder, partially full of atmospheric air, be placed under an air-pump receiver, as the pressure is removed it dilates to its full extent, and might even be burst by the elastic force of the air confined within. The force with which this expansion takes place is very well displayed by putting the bladder in a frame as shown in Fig. 12, and loading it with heavy weights; as it expands by the spring of the air, it lifts up all the weights.

Fig. 11.

If we were to imagine a given volume of gas placed in an immense vacuum, or under such circumstances that no extraneous agency could act upon it, it is very clear that its expansion would be indefinitely great—the repulsive force of its own particles predominating over their attraction, and there being nothing to limit their retreat from one another. But when a gaseous mass surrounds a solid nucleus, the case is different—an expansion to a determinate and to a limited extent is the result. And these are the circumstances under which the earth and every planet surrounded by an elastic

atmosphere exists; for in the same way that our globe compels an unsupported body to fall to its surface, and makes projectiles, as bomb-shells and cannon-shot—no matter what may have been the velocity with which they were urged—return to the ground, so the same attractive force restrains the indefinite expansion of the air and keeps the atmosphere, instead of diffusing away into empty space, imprisoned all round.

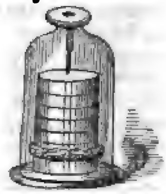

Fig. 12.

Besides this cause, gravitation to the earth, a second one, for the limited extent of the atmosphere, may also be assigned—contraction, arising from cold. Observation has shown that, as we rise to greater altitudes in the air, the cold continually increases; and gases, in common with all other forms of body, are condensed by cold. The attempt at unlimited expansion which the atmosphere, by reason of its gaseous constitution exerts, is therefore, kept in bounds by two causes—the attractive force of the earth and cold—and accordingly its altitude does not exceed fifty miles.

From the circumstances that air is thus a compressible body, we might predict one of the leading facts respecting the constitution of the atmosphere—it is of unequal densities at different heights. Those portions of it which are down below have to bear the weight of the whole superincumbent mass; but this weight necessarily becomes less and less as we advance to regions which are higher and higher; for in those places, as there is less air to press, the pressure must be less. And all this is verified by observation. The portions which rest on the ground are of the greatest density, and the density steadily diminishes as we rise. [These facts may be illustrated by the following simple experiment:. Take four bags of wool and place them one above the other. It will then be evident that the lowest bag is compressed by the other three above it, while the bag that is placed upon the top is entirely uncompressed. Now, it is thus with the particles of which the air is composed, for we find that at the earth's surface tho air is denser then on the top of a mountain.] Moreover a little consideration will assure us that there is a very simple relation between the pressure which the air exerts and its elastic force. Consider the condition of things in the air immediately around us: if its elastic force were less, the weight of the superincumbent mass would crush it in; if greater, the pressure could no longer restain it, and it would expand. It follows, therefore, in the necessity of the case, that the elastic force of any gas is neither greater nor less, but precisely equal to the pressure which is upon it.

CHAPTER IV.

WEIGHT AND PRESSURE OF THE AIR.

Description of the Air-pump—Its Action—Limited Exhaustion—Fundamental fact that Air has Weight—Relative Weight of other Gases—Weight gives rise to Pressure—Experiments illustrating the Pressure of the Air.

In the year 1560, Otto Guericke, a German, invented the air-pump, and exhibited a number of very striking experiments before the Emperor Ferdinand III. This incident forms an epoch in physical science.

Otto Guericke's instrument was imperfect in construction and difficult of management. The apparatus required to be kept under water. More convenient machines have therefore been devised. The following is a description of one of the most simple:—Upon a metalic basis, *h h*, Fig. 13, are fastened two exhausting syringes, *a a*, which are worked by means of a handle, *b*, the two screw columns, *e e*, aided by the cross piece, *ff*, tightly compressing them into their places. A jar, *c*, called a receiver, the mouth of which is carefully ground true, is placed on the plate of the pump, *h h*, which is formed of a piece of metal or glass ground quite flat. This pump-plate is perforated in its centre, from which air-tight passages lead to the bottom of each syringe, and when the handle, *b*, is moved, the syringes withdraw the air from the interior of the jar. From the same central perforation there is a third passage, which can be opened or closed by the screw at *g*, so that when the experiments are over, by opening it, the air can be re-admitted into the interior of the receiver.

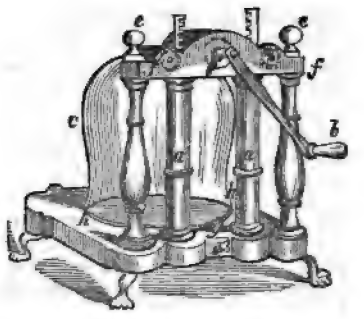

Fig. 13.

So far as its exterior parts are concerned, this air-pump consists of a pair of syringes worked by a handle, and producing exhaustion of the interior of a jar, with a vent which can be closed or opened for the re-admission of air.

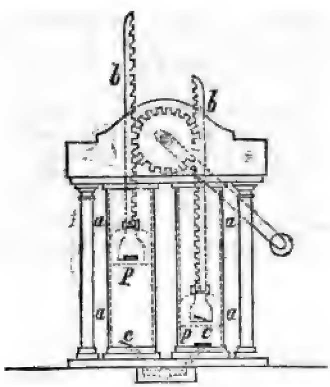

Fig. 14.

The syringes are constructed exactly alike. The glass model, represented in Fig. 14, exhibits their interior; each consists of a cylinder, *a a*, the interior of which is made perfectly true, so that a piston, *p*, introduced at the top may be pushed to the bottom, and, indeed, work up and down without any leakage. There is a hole made through the piston, *p*, and over it a valve is laid. This consists of a flexible piece of membrane,—as leather, silk, &c.,—which being placed on the aperture, opens in one direction, and closes in the other. Such a valve is in the piston, and there is another one, *c*, resting on an aperture in the bottom of the cylinder.

To understand the action of this instrument, let us suppose a glass globe, full of atmospheric air, to be fastened air-tight to the bottom of such a syringe, and the piston then lifted to the top of the cylinder. As it moves without leakage, it would evidently leave a vacuum below it, were it not that the air in the globe, exerting its elastic force, pushes up the valve, *c*, and expands into the cylinder. In this way, therefore, by the upward

movement of the piston, a certain quantity of air comes out of the globe and fills the cylinder. The piston is now depressed: the moment it begins to descend the valve, *c*, which leads into the globe, shuts; and now, as the piston comes down, it condenses the air below it, and as this air is condensed, it resists exerting its elastic force. The piston-valve, *p*, under these circumstances, is pushed open, and the compressed air gets away into the atmosphere. As soon as the piston has reached the bottom of the cylinder all the air has escaped, and the process is repeated precisely as before. The action in the syringe is, therefore, to draw out from the globe a certain quantity of air at each upward movement, and expel this quantity into the air at each downward movement.

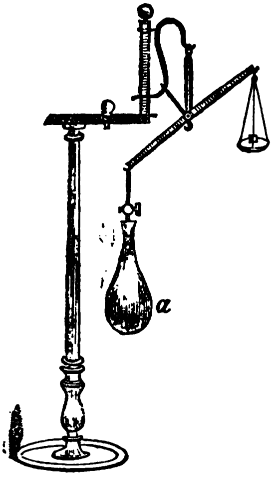

Fig. 15.

For reasons connected with the great pressure of the air, and also for expediting the process of exhaustion, two syringes are commonly used. To their pistons are attached rods which terminate in racks, *b b*; between these is placed a toothed wheel, which is turned on its axis by the handle, its teeth taking into the teeth of the racks. When the handle is set in motion, and the wheel made to revolve, it raises one of the pistons, and at the same time depresses the other. The ends of these racks are seen in Fig. 14. The wheel is included in the transverse wooden bar, *f f*, Fig. 13.

By the aid of this invaluable machine numerous striking and important experiments may be made. The form described here is one of the most simple, and by no means the most perfect. For the higher purposes of science, more complicated instruments have been contrived, in which, with the utmost perfection of workmanship, the valves are made to open by the movements of the pump itself, and do not require to be lifted by the elastic force of the air. In such pumps, a far higher degree of rarefaction can be obtained.

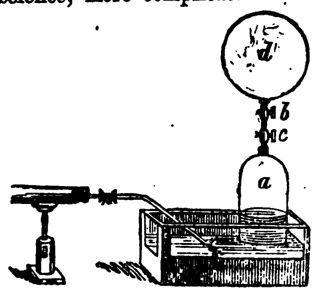

Fig. 16.

No air-pump, no matter how perfect it may be, can ever make a perfect vacuum, or withdrew all the air from its receiver. The removal of the air depends on the expansion of what is left behind, and there must always be that residue remaining which has forced out the portion last removed by the action of the syringes.

The fundamental fact in the science of Pneumatics is, *that atmospheric air is a heavy body*, and this may be proved in a very satisfactory manner by the

pressure from one side of a body, be exerted on the other, we see evidence of the in- Thus, if we take at both ends, and the pump-plate, lay on the mouth of the air, the hand is with the jar, so lifted without the

Fig. 18.

piece of bladder, and allow it to dry, position; but on exhausting the depressed, and is soon burst in- instance illustrates, in a very pressure of the air is thus rendered exhausted, and had air in its interior, could not force the bladder inward, for any such disturbance to take elastic force of the air within, which site way. But on the removal of the above is no longer antagonized, and it bladder.

HAPTER V.

URE OF THE AIR.

Water supported by Air—The Pneumatic Barometer—Cause of its Action—Different surement of Accessible Heights.

establish the fact that the atmosphere presses, the downward direction, but also in every other if we take a pair of hollow brass hemispheres, which fit together without leakage, by means and exhaust the air from their interior through affixed to one of them, it will be found pulled apart, except by the exertion [In order to make the contact of the hemispheres are rubbed the air being exhausted.] Now it the handles of these hemispheres represented in the figure, or turned a angle to the horizon, they adhere with equal which is required to pull them asunder

aid of the pump. Let there be a glass flask, *a*, Fig. 15, the mouth of which is closed with a stop-cock, through which the air can be removed. If from this flask we exhaust all the air, and then equipoise it with weights at a balance, as soon as the stop-cock is opened and the air allowed to rush in, the flask preponderates. By adding weights in the opposite scale, we can determine how much it requires to bring the balance back to equilibrio, and therefore what is the weight of a volume of air equal to the capacity of the flask.

Upon the same principles we can prove that all gasses, as well as atmospheric air, have weight. It is only requisite to take the exhausted flask, and having counterpoised it as before, screw it on the top of a jar, *a*, Fig. 16, containing the gas to be tried. On opening the stop-cocks, *b c*, the gas flows out of the jar and fills the flask, which, being removed, may be again counterpoised at the balance, and the weight of the gas filling it determined. There are very great differences among gases in this respect.

The following table will show the respective weights of equal quantities by measure of several elastic fluids, including those which are of the greatest importance on account of their frequent occurrence, and the valuable purposes to which they have been applied :—

	Weight of 100 cubic inches.	Specific Gravity.
Atmospheric air..............	30· 5 grains.	1·
Oxygen gas..................	33· 8 ,,	1·111
Nitrogen gas	29.25 ,,	0·972
Nitrous oxide...............	46· 6 ,,	1·527
Hydrogen gas	2·12 ,,	0·069
Carbonic acid...............	46· 5 ,,	1·529
Chlorine gas	76· 3 ,,	2·500
Sub-carburetted hydrogen	16· 9 ,,	0·555
Carburetted hydrogen	29. 6 ,,	0.972
Steam	18· 8 ,,	0·519

The specific gravity of the atmosphere being the standard with which the density of all gaseous substances is compared, it is considered as unity. [At 30 Bar. and 32 deg. it is 769·4 times lighter than water, and 10,462 than mercury: or at 62 deg. 815 times lighter than water, and 11,065 times lighter than mercury. The knowledge of its exact weight is an essential element in many physical and chemical researches, and has been determined with very great care by Prout, who finds that 100 cubic inches of pure and dry atmospheric air at 60 deg. and 30 Bar. weigh 31·0117 grains.—*Turner's "Elements of Chemistry."*]

From the fact that the air has weight, it necessarily follows that it exerts pressure on all those portions that are in the lower regions, having to sustain the weight of the masses above. And not only does this hold good as respects the aërial strata themselves; it also holds for all objects immersed in the air. In most cases, the resulting pressure is not detected, because it takes effect equally in all directions, and pressures that are equal and opposite mutually neutralize each other.

But when by the air-pump we remove the pressure from one side of a body, and still allow it to be exerted on the other, we see at once abundant evidence of the intensity of this force. Thus, if we take a jar, Fig 17, open at both ends, and having placed it on the pump-plate, lay the palm of the hand on the mouth of it: on exhausting the air, the hand is pressed in firm contact with the jar, so that it cannot be lifted without the exertion of a very considerable force.

Fig. 17.

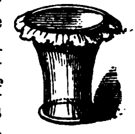

Fig. 18.

In the same way, if we tie over a jar a piece of bladder, and allow it to dry, it assumes, of course, a perfect horizontal position; but on exhausting the air within very slightly, it becomes deeply depressed, and is soon burst inward with a loud explosion. This simple instance illustrates, in a very satisfactory way, the mode in which the pressure of the air is thus rendered obvious; for so long as the jar was not exhausted, and had air in its interior, the downward pressure of the atmosphere could not force the bladder inward, nor disturb its position in any manner: for any such disturbance to take place, the pressure must overcome the elastic force of the air within, which resists it, pressing equally in the opposite way. But on the removal of the air from the interior, the pressure above is no longer antagonized, and it takes effect at once by crushing the bladder.

CHAPTER V.

THE PRESSURE OF THE AIR.

The Magdeburgh Hemisphere—Water supported by Air—The Pneumatic Trough—Description of the Barometer—Cause of its Action—Different kinds of Barometers—Measurement of Accessible Heights.

MANY beautiful experiments establish the fact that the atmosphere presses, not only in the downward direction, but also in every other way. Thus, if we take a pair of hollow brass hemispheres, *a b*, Fig. 19, which fit together without leakage, by means of a flange, and exhaust the air from their interior through a stop-cock affixed to one of them, it will be found that they cannot be pulled apart, except by the exertion of a very great force. [In order to make the contact more perfect, the hedges of the hemispheres are rubbed with grease previous to the air being exhausted.] Now it does not matter whether the handles of these hemispheres are held in the position represented in the figure, or turned a quarter way round, or set at any angle to the horizon, they adhere with equal force together; and the same power which is required to pull them asunder in

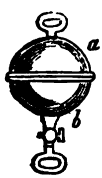

Fig. 19.

the vertical direction must also be exerted in all others. This, therefore, proves that the pressure of the air takes effect equally in every direction, whether upward or downward, or laterally.

[This experiment merits recollection, because it was one of the first which drew attention to the material nature and properties of the air, and it astonished the world. Otto de Guericke, of Magdeburgh, the inventor, had hemispheres made a foot in diameter; and once when he exhausted them, on the occasion of a public exhibition, six coach-horses of the Emperor were unable to pull them asunder.—*Arnott's "Elements of Physics."*]

[Two small hemispheres of copper were exhausted and placed between four strong dray-horses; but they could not separate them although dragging in opposite directions for about half an hour.]

Take a wine-glass, and having filled it entirely with water, place over its mouth a slip of writing-paper. If the wine-glass be inverted, it will be seen that the fluid is supported, the paper neither dropping off nor the water flowing out. This remarkable result illustrates the doctrine of the upward pressure of the air. Nor does it even require that a piece of paper should be used, provided the glass has the proper form. Thus, let there be a bottle, *a*, Fig. 20, in the bottom of which there is a large aperture, *b*. If the bottle be filled with water, and its mouth closed by the finger, the water will not flow out, but remain suspended. And that this result is due to the upward pressure of the air is proved by moving the finger a little on one side, so as to let the air exert its pressure on the top as well as the bottom of the water, which immediately flows out.

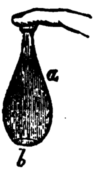

Fig. 20.

If we take a jar, *a*, Fig. 21, and having filled it full of water, invert it, as is represented, in a reservoir, or trough; for the reason explained in reference to Fig. 19, the water will remain suspended in the jar. Such an arrangement forms the pneumatic trough of chemists. It enables them to collect the various gases without intermixture with atmospheric air; for if a pipe, or tube, through which such a gas is coming be depressed beneath the mouth of the jar, *a*, so that the bubbles may rise into the jar, they will displace the water, and be collected in the upper part without any admixture.

If in this experiment we use mercury instead of water, the same phenomenon ensues—the mercury being supported by the pressure of air. Now, it might be inquired, as the atmosphere only extends to a certain altitude, and therefore presses with a weight which, though great, must necessarily be limited, whether that pressure could sustain a column of mercury of an unlimited length? If we take a jar a yard in length, and fill it with mercury, and invert it in a trough, it will be seen that the mercury is not supported, but that it settles from the top and descends until it reaches a point which is about thirty inches above the level of the mercury in the trough. Of course, as nothing has been admitted, there must be a vacant space or vacuum between the top of the mercury and the top of the jar.

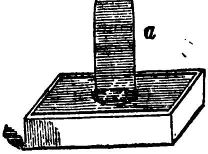

Fig. 21.

This experiment, which, as we are soon to see, is a very important one, is

commonly made with a tube, *a b*, Fig. 22, instead of a jar—the tube being more manageable, and containing less mercury. It should be at least thirty-two inches long, and being filled with quicksilver, may be inverted in a shallow dish, containing the same metal, *c*. It is convenient to place at one side of the tube a scale, *d*, divided into inches, these inches being counted from the level of the mercury in the dish, *c*. Such an instrument is called a Barometer, or measurer of the pressure of the air.

Fig. 22.

Let us briefly investigate the agencies which operate in the case of this instrument. If, having closed the mouth of the tube, *b*, with the finger, we lift it out of the dish, *c*, it will be found that we must exert a considerable degree of force in order to sustain the column of mercury, which presses against the finger with its whole weight, and tends to push it away. Consequently, the mercury is continually exerting a tendency to flow out, and therefore two forces are in operation; on the one hand, the weight of the mercury attempting to flow out of the tube into the dish; and on the other, the weight or pressure of the atmosphere attempting to push the mercury up in the tube. If the pressure of the air were greater, it would push the mercury higher; if less, the mercury would flow out to a corresponding extent. Thus, the length of the mercury column equilibrates the pressure of the air, and we therefore say that the atmospheric pressure is equal to so many inches of mercury.

That the whole thing depends on the pressure of the air may be beautifully proved by putting the barometer under a tall air-pump receiver, as represented in Fig. 23, and exhausting. As the pressure of the air is reduced, the mercurial column falls; and if it were possible to make a perfect vacuum by such means, the mercury would sink in the tube to its level in the dish. On re-admitting the air the mercury rises again, and when the original pressure is regained it stands at the original level.


Fig 23.

There are many different forms of barometers, such as the straight, the syphon, &c., but the principle of all is the same. The scale must uniformly commence at the level of the mercury in the reservoir. Now, it is plain that this level changes with the height of the column; for if the metal flows out of the tube, it raises the level in the reservoir, and *vice versâ*. In every perfect barometer, means, therefore, should be had to adjust the beginning of the scale to the level for the time being. In some barometers, as in that represented in Fig. 24, this is done by having the mercury in a cistern with a moveable bottom, and by turning the screw V, the level can be precisely adjusted to that of the ivory point, *a*.

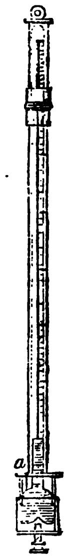

Fig. 24.

A barometer kept in the same place undergoes variations of altitude, some of which are regular, and others irregular. The former, which depend on diurnal tides in the atmosphere, analogous to tides in the sea, occur about

the same time of the day—the greatest depression being commonly about four in the morning and evening, and the greatest elevation about ten in the morning and night. In summer, however, they occur an hour or two earlier in the morning, and as much later at night. The irregular changes depend on meteorological causes, and are not reduced as yet to any determinate laws. In amount they are much more extensive than the former, extending from the twenty-seventh to more than the thirtieth inch, while those are limited to about the tenth of an inch.

A very valuable application of the barometer is for the determination of accessible heights. The principle upon which this depends is simple—the barometer necessarily standing at a lower point as it is carried to a higher position. In practice it is more complicated; and to obtain exact results various methods have been given by Laplace, Bailly, Littrow, and others.

[The pressure of the atmosphere varies according to the elevation above the level of the sea, and on this principle the height of mountains is estimated. Supposing the density of the atmosphere to be uniform, a fall of one inch in the barometer would correspond to 11,065 inches, or 922 feet of air; but in order to make the calculation with accuracy, allowance must be made for the increasing rarety of the air, and for various other circumstances which are detailed in works on meteorology.—*Turner's "Elements of Chemistry."*]

CHAPTER VI.

THE PRESSURE OF THE AIR.

Measure of the Force with which the Air presses—Different Modes of Estimating it—Experiments illustrating this Force—Elasticity of the Air—Experimental Illustrations—The Condenser.

Having explained the cause, and illustrated the pressure of the air, we proceed in the next place to determine its actual amount.

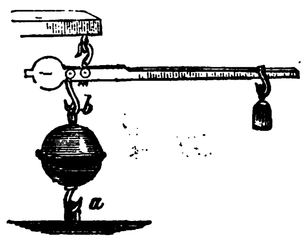

Fig. 25.

There are many ways in which this may be done. The following is simple: Take a pair of Magdeburgh hemispheres, the area of the section of which has been previously determined in square inches; exhaust them as perfectly as possible at the pump; and then, fastening the lower handle, *a*, to a firm support, hang the other, *b*, Fig. 25, to the hook of a steelyard, and move the weight until the hemispheres are pulled apart. It will be found that this commonly takes place when the weight is sufficient to overcome a pressure of fifteen pounds on every square inch.

This may serve as an elementary illustration, but there are other methods much more exact. Thus, by the barometer itself we may determine the

value of the pressure with precision. If we had a barometer which was exactly one square inch in section, and weighed the quantity of mercury it contained at any given time, it would give us the value of the atmospheric pressure on one square inch, because the weight of the mercury is equal to the pressure of the air. And by calculation we can, in like manner, obtain it from tubes of any diameter.

The phenomena of the barometer teach us that this pressure is not always the same, but it undergoes variations. It is commonly estimated at fifteen pounds on the square inch.

[The pressure of the atmosphere being about fifteen pounds on every square inch, the surface of the whole globe sustains a pressure of 11,449,000,000 hundreds of millions of pounds. Shell-fish, which have the power of producing a vacuum, adhere to the rocks by a pressure of fifteen pounds upon every square inch of contact.—*Somerville's "Connection of the Physical Sciences."*]

There are two other ways in which the value of the pressure of the air is stated. It is equal to a column of mercury thirty inches in length, or to a column of water thirty-four feet in length.

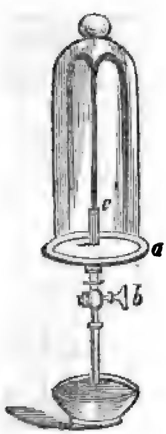

Fig. 26.

We are now able to understand the reason of the great effects to which the pressure of the air may give rise. In most instances these effects are neutralised by countervailing pressures. Thus, the body of a man of ordinary size has a surface of about two thousand square inches, the pressure upon which is equal to thirty thousand pounds. But this amazing force is entirely neutralised, because, as we have seen, the atmospheric pressure is equal in all directions—upward, downward, and laterally. All the cavities and the pores of the body are filled with air, which presses with an equal force. [What a fortunate thing it is that we are subjected to this apparent enormous pressure, for if this did not exist, the fluids that circulate within our bodies would be vapourised, and the surrounding parts crumble away.]

The following experiments may further illustrate the general principle of atmospheric pressure:

On a small flat plate, *a*, Fig. 26, furnished with a stop-cock, *b*, which terminates in a narrow pipe, *c*, let there be placed a tall receiver, from which the air is to be exhausted by the pump. The stop-cock, *b*, being closed, and the instrument being removed from the pump, *b* is to be opened, while the lower portion of its tube dips into a bowl of water. Under these circumstances the water is pressed up in a jet through *c*, and forms a fountain in vacuo.

Fig. 27.

On the top of a receiver, Fig. 27, let there be cemented air-tight, a cup of wood, *a*, terminating in a cylindrical piece, *b*, the pores of which run lengthwise. Beneath this let there be placed a tall jar, *c*. Now, if the wooden cup be filled with quicksilver, the jar being previously placed on the pump, and exhaustion made, the metal will be

pressed through the pores of the wood and descend in a silver shower. The jar, *c*, should be so placed as to prevent any of the quicksilver getting into the interior of the pump.

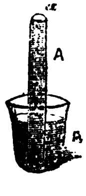

Fig. 28.

There are many substances which exist in the liquid condition, merely because of the pressure of the air. Take a glass tube, A, Fig 28, closed at one end and open at the other, and having filled it with water, invert it in a jar, B; introduce into it now a little sulphuric ether, which will rise, because of its lightness, to the top of the tube, at *a*. Place the apparatus beneath the receiver of the air-pump, and exhaust. The ether will now be seen to abandon the liquid, and assume the gaseous form, filling the entire tube and looking like air. On allowing the pressure again to take effect, it again relapses into the liquid form.

The following experiments illustrate the elasticity of the air:

Take a glass bulb, *a*, Fig. 29, which has a tube, *b*, projecting from it, the open extremity of which dips beneath some water in a cup, *c*; the tube and the bulb being likewise full of water, except a small space which is occupied by a bubble of air at *a*. Invert over the whole a jar, *d*, and, placing the arrangement on the pump, exhaust. It will be found, as exhaustion goes on, that the bubble, *a*, steadily increases in size until it fills all the bulb, and even the tube. On re-admitting the pressure, the bubble collapses to its original size. The air is, therefore, dilatable and condensible—that is, it is elastic.

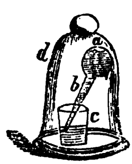

Fig. 29.

If a bottle, the sides of which are square and the mouth hermetically closed, be placed beneath a receiver, and the pressure removed, the air imprisoned in the interior, exerting its elastic force, will violently burst the bottle to pieces. It is, therefore, well to cover it with a wire cage, as represented in Fig. 30.

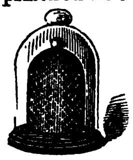
Fig. 30.

The elastic force of the air increases with its density. Powerful effects therefore arise by condensing air into a limited space. The condenser, which is an instrument for this purpose, is represented in Fig. 31. It consists of a tube, *a*, *b*, in which there moves by a handle, *g*, a piston, *f*. In one side of the tube, at *c*, there is an aperture, and at the lower part, *d*, there is a valve, *e*, opening downward. On pushing the piston down, the air beneath it is compressed, and, opening the valve, *e*, by its elastic force, accumulates in the receiver, R. When the piston is pulled up, a vacuum is made in the tube; but as soon as it passes the aperture, *c*, the air rushes in. Another downward movement drives this through the valve into the receiver, and the process may be continued until the elastic force of the included air becomes very great.

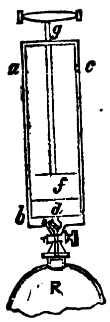

Fig. 31.

If the receiver be partly filled with water, and there be placed in it a piece of wax, an egg, or any yielding or brittle bodies, it will be found impossible to alter their figure by condensing the air to any extent whatever. And

this arises from the circumstance already explained—that the pressure generated is equal in all directions.

[A common toy, known by the name of the water balloon, is constructed upon the following scientific principles:—The figure of a balloon is blown in glass, and the lower part, which is curved for the car to be attached, has a small hole in it. A car is then suspended to it, and this is of such a weight that it is *exactly* balanced by the balloon full of air placed in a tall vessel of water, covered with a piece of bladder or india-rubber, which is firmly tied over the top. By pressing the finger on the cover, the balloon will descend to the bottom, and on removing the finger, the elastic force of the air in the balloon drives out the excess of water which had previously entered, and the balloon becoming lighter, re-ascends. Therefore, we say that the ascent and descent of the balloon depends upon the condensation and expansion of the air contained in it.]

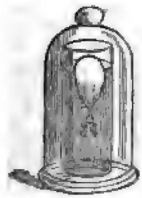
Fig. 32.

On precisely the same principle, if a small bladder, only partly full of air, be sunk by a weight, Fig. 32, to the bottom of a deep glass of water, on covering the whole with a receiver, and exhausting the elastic force of the included air, dilates the bladder, which rises to the top, carrying with it the weight. When the pressure is re-admitted, the bladder collapses and descends again to the bottom of the jar.

There are numerous machines in which the elastic force of air is brought into operation, such as the air-gun, blowing-machines, &c. Indeed, the various applications of gunpowder itself depend on this principle—that material on ignition suddenly giving rise to the evolution of an immense quantity of gas, which exerts a great elastic force.

CHAPTER VII.

PROPERTIES OF THE AIR.

Marriotte's Law—Proof for Compressions and Dilatations—Case in which it Fails—Resistance of the Air to Motion—The Parachute—The Air transmits Sound; supports Animal Life, Combustion, and Ignition—Exists in the pores of some bodies and is dissolved in others.

ATMOSPHERIC air being thus a highly compressible and expansible substance, we have next to inquire what is the amount of its compressibility under different degrees of force? This has been determined experimentally by different philosophers, the true law having first been discovered by Boyle and Marriotte.

The density and elasticity of air are directly as the force of compression.

The volume which dir occupies is inversely as the pressure upon it.

To illustrate, and at the same time to prove these laws, we make use of a

tube, *a d c b*, so bent that it has two parallel branches, *a* and *b*. It is closed at *b*, and has a funnel-mouth at *a*. Sufficient mercury is poured into the tube to close the bend and to insulate a volume of air in *b d*. Of course this air exists under a pressure of one atmosphere equal to a column of mercury thirty inches long. Through the funnel, *a*, mercury is now to be poured; as it accumulates it presses on the air in *d b*, and reduces its volume to *c*. If, in this manner, a column thirty inches long be introduced, it will be found that the air in *b d* is reduced to half. There are, therefore, now two atmospheres pressing on the included air—the atmosphere itself being one, and the thirty inches of mercury the other. Two atmospheres, therefore, reduce a given quantity of air into half its volume.

Fig. 33.

In the same manner it could be proved, if the tube were long enough, that the introduction of another thirty inches of mercury, giving a pressure of three atmospheres, would condense the air to one-third, that four would compress it to one-fourth, five to one-fifth, &c.

[The truth of this law may be proved for rarefactions as well as condensations. Arago and Dulong have demonstrated that Marriotte's law does not vary for atmospheric air in its application to a pressure of twenty-seven atmospheres.] For this purpose let there be taken a long tube, *a b*, Fig. 34, open at the end, *b*, and closed at *a*, with a screw; a jar, B, filled with mercury to a sufficient height, is also to be provided. Now let the screw at *a* be opened and the tube depressed in the mercury until the metal, by rising, leaves in the tube a few inches of air. The screw is now to be closed and the tube lifted. The included air at once dilates, and a column of mercury is suspended. It will be found that when the air has dilated to double its volume, the length of the mercurial column in the tube will be fifteen inches—that is, half the barometic length.

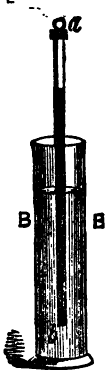

Fig. 34.

By such experiments it therefore appears that Marriotte's law holds both for condensations and rarefactions. This law has been verified until the air has been condensed twenty-seven times and rarefied one hundred and twelve times. In the case of gases, which easily assume the liquid form, it is, however, departed from as that point is approached.

Besides the properties already described, atmospheric air possesses others which require notice. Among these may be mentioned resistance to motion.

This property may be exhibited by means of the two wheels, *a b*, Fig. 35, which can be put in rapid rotatory motion by the rack, *d*, which moves up and down through an air-tight stuffing-box, *e*. The wheels are so arranged that the vanes of *a* move through the air edgewise, but those of *b* with their broad faces. On pushing down the rack, *d*, and making the wheels rotate with equal rapidity in the atmospheric air, one of them, *a*, will be found to continue its motion much longer than the other, *b*; and that this arises from the resistance which *b* experiences from the air is proved by making them rotate in the receiver from which the air has been exhausted, when *b* will continue its motion as long as *a*, both ceasing to revolve simultaneously.

The water-hammer affords another instance of the same principle. It

consists of a tube a foot or more long, and half an inch in diameter. In it there is included a small quantity of water, but no atmospheric air. When it is turned upside down the water drops from end to end, and emits a ringing metallic sound. If there were any air in the tube, it would resist or break the fall of the water. A well-made mercurial thermometer exhibits the same fact. If there is a perfect vacuum in its tube, on turning the instrument upside down the metal drops like a hard, solid body against the closed end.

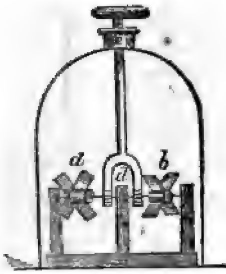

Fig. 35.

THE PARACHUTE is a machine by which aëronauts may descend from a balloon to the ground in safety. It bears a general resemblance to an umbrella, and consists of a strong but light surface, *a a*, Fig. 36, from which a car, *b*, is suspended. When it is detached from the balloon it descends at first with an accelerated velocity; but this is soon checked by the resistance of the air, and the machine then falls at a rate nearly uniform, and very moderate.

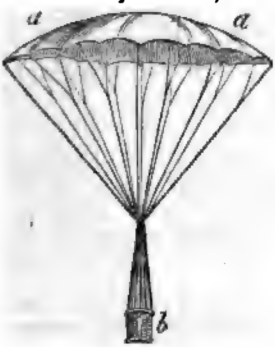

Fig. 36.

[A very simple experiment will enable any person to illustrate the principle of the parachute. Take a piece of paper about three feet square, and attach a piece of thread to each corner of it; then fasten a proportionate weight to the lower part, and let it drop from a window, or even from your hand, held as high as you can. It will descend slowly to the ground.]

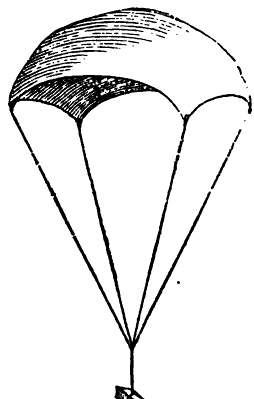

Fig. 37.

[Zacharia of Rosleben conceived that it would be possible to construct a flying boat, and, as an experiment he made a case of light wood, covered with linen, in the shape of a flat obtuse-angled keel, five and a half feet in diameter, and half a foot deep, weighing fourteen and a half pounds. He launched this machine from a scaffold twenty-seven feet high, which was erected on a rock one hundred feet above the racecourse of Wendelstein, 17th of September, 1822, and the boat flew 153 feet. He made another experiment upon the same day, and from the same spot, with another boat, weighing twenty-five pounds, which landed after a flight of 158 feet. The experiments were not repeated, on account of the expense and their partial failure.—*Abridged from the "Elements of Natural Philosophy," by Prof. Viest, of Anhalt-Dessau, page* 207.]

In virtue of its elasticity, atmospheric air is the common medium for the transmission of sounds. Under the receiver of an air-pump, let there be placed a bell, *a*, Fig. 38, the hammer, *b*, of which can be moved on its pivot, *c*, by means of a lever, *h*, which is worked by a rod passing through the stuffing-box, *e*. The bell is placed on a leather drum, *f*, and fastened down to the pump-plate by means of a board, *d*. While the air is yet in the receiver, the sound is quite audible, but on exhausting, it becomes fainter and fainter, and at last can no longer be heard. On re-admitting the air the sound gradually increases, and at last acquires its original intensity. The leather cushion, *f*, is necessary to prevent the transmission of the sound through the solid part of the pump.

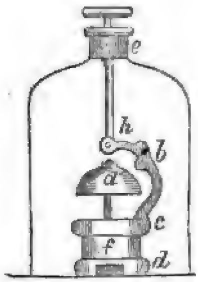

Fig. 38.

The air also is absolutely necessary for the support of life. The higher warm-blooded animals die when the air is only partially rarefied. A rabbit, or other small animal, placed under an air-pump jar, may remain there several minutes without being much disturbed; but if we commence with drawing the air, the animal instantly shows signs of distress, and if the experiment is continued, soon dies. (Fig. 39.)


Fig. 39.

So, too, if a jar containing some small fishes be placed under an exhausted receiver, the animals either float on their backs, at the surface of the water; or descend only by violent muscular exertions. Fishes respire the air which is dissolved in water, and hence it is somewhat remarkable that they continue to live for a considerable length of time in an exhausted receiver.

The air is also necessary to all processes of combustion. If a lighted candle be placed under a receiver, it will burn for a length of time; but if the air be withdrawn by the pump, it presently dies out. The smoke also descends to the bottom of the receiver, there being no air to buoy it up.

If a gun-lock be placed in an exhausted receiver, and the flint be made to strike, no sparks whatever appear; and, consequently, if there were powder in the pan, it could not be exploded. The production of sparks by the flint and steel is due to small portions of the latter which are struck off by the percussion burning in the air, and when the air is removed that combustion can of course no longer take place. (Fig. 40.)

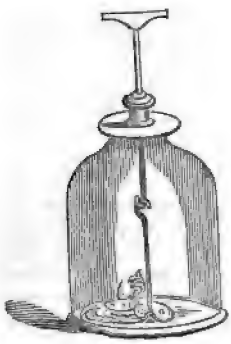
Fig. 40.


Fig. 41.

By taking advantage of the expansibility of the air, we are able to prove that it is included in the pores of many bodies. Thus, if an egg is dropped into a deep jar of water, and this covered with a receiver, as soon as exhaustion is made, a multitude of air-bubbles continually ascend through the water. (Fig. 41.) Or if a glass of porter be placed beneath such a receiver, its surface is covered with a foam, the carbonic acid gas, which is the cause of its agreeable briskness, escaping away. (Fig. 42.) And even common river or spring water treated in the same manner exhibits the escape of a considerable quantity of gas, which ascends through it in small bubbles, and gives it a sparkling appearance

Fig. 42.

CHAPTER VIII.

PROPERTIES OF THE AIR.

Loss of Weight of Bodies in the Air—Theory of Aerostation—The Montgolfier Balloon—The Hydrogen Balloon—Mode of Controlling Ascent and Descent—Artificial and Natural Currents in the Air—Resistance of the Air to Projectiles—Velocity with which Air flows into a Vacuum. Velocity of Efflux of different Gases—Principles of Gaseous Diffusion—These principles regulate the Constitution of the Atmosphere.

On principles which will be fully explained when we come to speak of specific gravity, it appears that a solid immersed in a fluid loses a portion of its weight. It follows, of course, that a substance weighs less in the air than it does in vacuo.

To the arm of the balance, *a*, Fig. 43, let there be hung a light glass globe, *c*, counterpoised in the air on the other arm, *b*, by means of a weight, *d*. If the apparatus be placed beneath a receiver, and the air exhausted, the globe, *c*, descends, but on re-admitting the air the equilibrium is again restored. This instrument was formerly used for determining the density of the air.

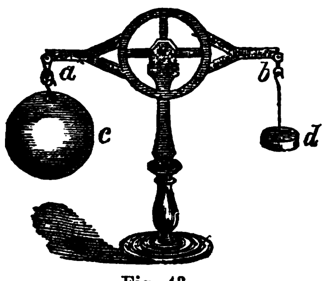

Fig. 43.

A substance that has the same density as atmospheric air, when it is immersed in that medium, loses all its weight, and will remain suspended in it in any position in which it may be placed. But if it be lighter, it is pressed upward by the aërial particles, and rises, upon the same principle that a cork ascends from the bottom of a bucket of water. And as the density of the air continually diminishes as we go upward, it is evident that such a body, ascending from one stratum to another, will finally attain one having the same density as itself, and there it will remain suspended.

On these principles aerostation depends. Air balloons are machines which ascend through the atmosphere and float at a certain altitude. They are of two kinds: first, Montgolfier, or rarefied air balloons; and second, Hydrogen gas balloons.

The Montgolfier balloon, which was invented by the person whose name it bears, consists of a light bag of paper, or cotton, which may be of a spherical or other shape; in its lower portion there is an aperture, with a basket suspended beneath for the purpose of containing burning material, as straw or shavings. On a small scale, a paper globe two or three feet in diameter, with a piece of sponge soaked in spirits of wine, answers very well. The hot air arising from the burning matter enters the aperture, distending the balloon, and makes it specifically lighter than the air, through which, of course, it will rise. (Fig. 44.)

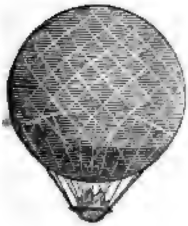

Fig. 44.

The hydrogen gas balloon consists, in like manner, of a thin, impervious bag, filled either with hydrogen or common coal gas. The former, as usually made, is from ten to thirteen times lighter than air; the latter is somewhat heavier. A balloon filled with either of these possesses, therefore, a great ascensional power, and will rise to considerable heights. Thus, Biot and Gay Lussac, in 1804, ascended in one of these machines to an elevation of 23,000 feet. When the balloon first ascends, it ought not to be full of gas, for as it reaches regions where the pressure is diminished, the gas within it is dilated, and though flaccid at first, it will become completely distended. [A balloon which is only half full at the surface of the earth, becomes quite full when it has risen three miles and a half; because at that altitude, air from below doubles its volume on account of the diminished pressure.—*Dr. Arnott's "Elements of Physics," 3rd ed. p.* 401.] If it were full at the time it left the ground, there would be risk of its bursting open as it rose. The gas balloon requires a valve placed at its top, so that gas may be discharged at pleasure, and the machine made to descend. The aeronaut has control over its motions by taking up with him a quantity of sand in bags, as ballast. If he throws out sand, the balloon rises; and if he opens the valve, and lets the gas escape, it descends.

The rarefaction which air undergoes by heat makes it, of course, specifically lighter. Warm air, therefore, ascends, and cold air descends. When the door of a room which is very warm, is open, the hot air flows out at the top, and the cold enters at the floor; these currents may be easily traced by holding a candle near the bottom and top of the door. In the former position the flame leans inward, in the latter it is turned outward, following the course of the draught.

The drawing of chimneys, and the action of furnaces and stoves, depend on similar principles; the column of hot air contained in the flue ascending, the cold air replacing it below.

Similar movements take place in the open atmosphere. When the sun shines on the ground or the surface of the sea, the air in contact becomes warm and rises; it is replaced by colder portions, and a continuous current is established. The direction of these currents is changed by a variety of circumstances, as the diurnal rotation of the earth, and other causes less

understood. On these depend the various currents known as breezes, trade-winds, storms, hurricanes.

The atmosphere does not rush into a void space instantaneously; but, under common circumstances of density and pressure, with a velocity of about 1,296 feet in one second. Its resisting action on projectiles moving through it with great velocities is intimately connected with this fact. A cannon ball moving through it with a speed of two or three thousand feet leaves a total vacuum behind it. and condenses the air correspondingly in front. It is, therefore, subjected to a very powerful pressure continually tending to retard it. [Though we should be led, as in hydraulics, to conclude that the resistance which air makes to moving bodies is as the square of their velocities, experiment appears to prove, especially when the velocity is great, that the resistance is partly proportional to the square, and partly to the simple power of the velocity.—*Playfair's "Nat. Philosophy," vol.* 1, *page* 276.] The rush of the air flowing into the vacuous spaces left by moving bodies is the cause of the loud explosions they make.

When gases of different densities flow from apertures of the same size, the velocities with which they issue are different, and are inversely as the square roots of their densities. The lighter a gas is, the greater is its issuing velocity; and, therefore, hydrogen, which is the lightest body, moves, under such circumstances, with the greatest speed.

The experiment represented in Fig. 45, illustrates these principles. Let there be a tube, *a b*, half an inch in diameter and six inches long, the end, *b*, being open and *a* closed with a plug of plaster of Paris, which is to be completely dried. Counterpoise this tube on the arm of a balance, and fill it with hydrogen gas, taking care to keep the plug dry, letting the open end, *b*, of the tube dip just beneath the surface of some water contained in a jar, C. In a very short time it will be discovered that the hydrogen is escaping through the plaster of Paris, and the tube, filling with water, begins to descend; and after a few minutes much of the gas will have gone out, and its place be occupied partly by atmospheric air, which comes in the opposite direction, and partly by the water which has risen in the tube.

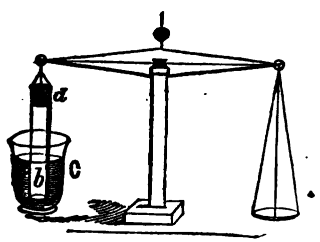

Fig. 45.

Even when gases are separated from each other by barriers, which, strictly speaking, are not porous, the same phenomenon takes place. Thus, if with the finger, we spread a film of soap-water over the mouth of a bottle, *a*, and then expose it under a jar to some other gas, such as carbonic acid, this gas percolates rapidly through the film, and, accumulating in the bottle, distends the film into a bubble, as represented in Fig. 46. Meanwhile, a little atmospheric air escapes out of the bottle through the film in the opposite direction.

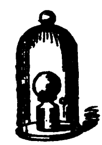
Fig. 46.

This propensity of gases to diffuse into each other is clearly shown by filling a bottle, H, Fig. 47, with a very light gas, as hydrogen; and a second one, C, with a heavy gas, as carbonic acid, and putting the bottles mouth to mouth. Diffusion takes place, the light

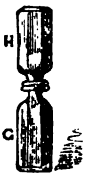

Fig. 47.

gas descending and the heavy one rising, until both are equally commixed. We see, therefore, that this property of gases is intimately concerned in determining the constitution of the atmosphere, which is made up of different substances, some of which are light and some heavy—the heavy ones not sinking nor the light ones ascending, but both kept equally commixed by diffusion into each other.

SECTION II.—Hydrostatics and Hydraulics.

CHAPTER IX.

PROPERTIES OF LIQUIDS.

Extent and Depth of the Sea—Its Influence on the Land—Production of Fresh Waters—Relation of Liquids and Gases—Physical Condition of Liquids—Different Degrees of Liquidity—Florentine Experiment on the Compression of Water—Oersted's Experiments—Compressibility of other Liquids.

Having disposed of the mechanical properties of atmospheric air, which is the type of gaseous bodies, in the next place we pass to the properties of water, which is the representative of the class of liquids.

About two-thirds of the surface of the earth are covered with a sheet of water, constituting the sea, the average depth of which is commonly estimated at about two miles. This, referred to our usual standards of comparison, impresses us at once with an idea of the great amount of water investing the globe; and, accordingly, imaginative writers continually refer to the ocean as an emblem of immensity.

But, referred to its own proper standard of comparison—the mass of the earth—it is presented to us under a very different aspect. The distance from the surface to the centre of the earth is nearly four thousand miles. The depth of the ocean does not, therefore, exceed $\frac{1}{200}$th part of this extent: and astronomers have justly stated, that were we on an ordinary artificial globe to place a representation of the ocean, it would scarcely exceed in thickness the film of varnish already placed there by the manufacturer.

In this respect the sea constitutes a mere aqueous film on the face of the globe. Yet, insignificant as it is in reality, it has been one of the chief causes engaged in shaping the external surface, and also of modelling the interior to a certain depth—for geological investigations have proved the former action of the ocean on regions now far removed from its influence, in the interior of continents; and also its mechanical agency in the formation of the sedimentary or stratified rocks which are of enormous superficial extents and often situated at great depths.

Besides the salt waters of the sea, there are collections of fresh waters, irregularly disposed, constituting the different lakes, rivers, &c. The direct sources of these are springs, which break forth from the ground, the little streams from which coalesce into larger ones. But the true source of all our

terrestrial waters is the sea itself. By the shining of the sun upon it a portion is evaporated into the air, and this, carried away by winds and condensed again by cold, descends from the atmosphere as showers of rain, which, being received upon the ground, percolates until it is stopped by some less pervious stratum, and flowing along this at last breaks out wherever there is opportunity in the low grounds—thus constituting a spring. Such streamlets coalesce into rivers, which find their way back again to the sea, the point from which they originally came—an eternal round, which is repeated for centuries in succession.

From these more obvious phenomena of Nature, we discover a relationship between aërial and liquid bodies—the one passing without difficulty into the other form—and, indeed, many of the most important events around us depending on that fact. Experiment also shows that, in many instances, substances which under all common circumstances exist in the gaseous condition, can be made to assume the liquid. Thus carbonic acid, which is one of the constituents of the atmosphere, can by pressure be reduced to the liquid form, and can even be made to assume that of a solid. The main agents by which such transmutations are effected are cold and pressure.

The parts of liquids seem to have little cohesion. Viewing the forms of matter as being determined by the relation of those attractive and repulsive forces which are known to exist among particles, it is believed in that now under consideration—the liquid—that these forces are in equilibrio. For this reason, therefore, the particles of such bodies move freely among one another; and liquids, of themselves, cannot assume any determinate shape, but conform their figure to the vessels in which they are placed. Portions of the same liquid added to one another readily unite.

Among liquids we meet with what may be termed different degrees of liquidity. Thus the liquidity of molasses, oil, and water, is of different degrees. It seems as though there was a gradual passage from the solid to this state, a passage often exhibited by some of the most limpid substances. Thus alcohol, when submitted to an extreme degree of cold, assumes that partial consistency which is seen in melting beeswax, yet at common temperatures it is one of the most mobile bodies known. So, too, that compound of tin and lead, which is used by plumbers as a solder, though perfectly fluid at a certain heat, passes, in the act of cooling, through various successive stages, and at a particular point becomes plastic and may be moulded with a cloth.

If a quantity of atmospheric air is pressed upon by any suitable contrivance, it shrinks at once in volume. We have already proved this phenomenon and determined its laws. If water is submitted to the same trial, the result is very different—it refuses to yield: for this reason, inasmuch as the same fact applies to the whole class, liquids are spoken of as incompressible bodies.

It was at one time thought that the experiment of the Florentine academicians, who filled a gold globe with water, and on compressing it with a screw found the water ooze through the pores of the gold, proved completely the incompressibility of that liquid.* But more recent experiments have

* The experiment alluded to by Professor Draper was performed at the Academy *Del Cimento*, in Florence, more than two centuries ago, and is now generally adduced to prove the porosity of gold in common with all other bodies.

shown, beyond all doubt, that liquids are compressible, though in a less degree than gases. Thus, it is a common experiment to lower a glass bottle, filled with water and carefully stopped with a cork, into the sea. On raising it again the cork is often found forced in, and the water is uniformly brackish. But in a more exact manner the fact can be proved, and even the amount of compressibility measured, by Oersted's machine. This consists of a strong glass cylinder, *a a*, Fig. 48, filled with water, upon which pressure can be exerted by a piston driven by a screw, *b*. When the screw is turned and pressure on the liquid exerted, it contracts into less dimensions, but at the same time the glass, *a a*, yielding, distends, and the contraction of the water becomes complicated with the expansion of the glass in which it is placed.

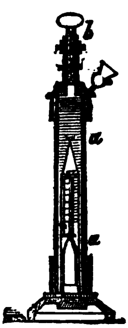

Fig. 48.

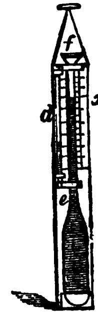

Fig. 48.

To enable us to get rid of this difficulty, the instrument, Fig. 48, is immersed in the cylinder of water, as seen at Fig. 49. This consists of a glass reservoir, *e*, prolonged into a fine tube, *e f*, with a scale, *x*, attached to it. The reservoir and part of the tube are filled with water, and a little column of quicksilver, *x*, is upon the top of the water, serving to show its position. On one side there is a gauge, *d*, partially filled with air. It serves to measure the pressure.

Now, when the instrument, Fig. 48, is put in the cylinder in the position indicated in Fig. 49, and pressure made by the screw, *b*, it is clear that the water in the reservoir will be compressed, and the glass which contains it being pressed upon equally, internally and externally, will yield but very little. Making allowance, therefore, for the small amount of compression which the glass thus equally pressed upon undergoes, we may determine the compressibility of the water as the force upon it varies. It thus appears that water diminishes $\frac{1}{22000}$ part of its volume for each atmosphere of pressure upon it. In the same way the compressibility of alcohol has been determined to be $\frac{1}{11000}$

CHAPTER X.

THE PRESSURE OF LIQUIDS.

Division of Hydrodynamics—Liquids seek their own Level—Equality of Pressure—Case of different Liquids pressing against each other—General Law of Hydrostatics—Hgdrostatic Paradox—Law for Lateral Pressures—Instantaneous communication of Pressure—Bramah's Hydraulic Press.

To the science which describes the mechanical properties of liquids the

title of HYDRODYNAMICS* is applied. It is divided into two branches, Hydrostatics† and Hydraulics ‡ The former considers the weight and pressure of liquids, the latter their motions in canals, pipes, &c.

A liquid mass exposed without any confinement to the action of gravity would spread itself into one continuous superficies, for all its parts gravitate independently of one another, each part pressing equally on all those around it, and being pressed on equally by them.

A liquid confined in a receptacle or vessel of any kind conforms itself to the solid walls by which it is surrounded, and its upper surface is perfectly plane, no part being higher than another. This level of surface takes place even when different vessels communicating with each other are used. Thus, if into a glass of water we dip a tube, the upper orifice of which is temporarily closed by the finger, but little water will enter, owing to the impenetrability of the air; but, as soon as the finger is removed, the liquid instantly rises, and finally settles at the same level inside of the tube that it occupies in the glass on the outside.

This result obviously depends on the equality of pressure just referred to, and it is perfectly independent of the form or nature of the vessel. If we take a tube bent in the form of the letter U, and closing one of its branches with the finger, pour water into the other, as soon as the finger is removed the liquid rises in the empty branch, and, after a few oscillatory movements, stands at the same level in both.

Fig. 50.

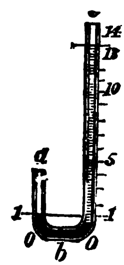

Fig. 51.

If one of the branches of such a tube is much wider than the other, the same result still ensues. Thus, as in Fig. 50, we might have a reservoir, A F, exposing an area of ten, or a hundred, or ten thousand times that of a tube rising from it, B G C H; but in the latter a liquid would rise no higher than in the former, both being at precisely the same level, A D. We perceive, therefore, from such an experiment, that the pressure of liquids does not depend on their absolute weight, but on their vertical altitude. The great mass of liquids contained in A exerts no more pressure on C than would a smaller mass contained in a tube of the same dimensions as C itself.

* From the Greek *udor* ("Υδωρ) water, and *dunamis* (Δυναμις) power. [Hydrodynamics is the science which applies the principles of Dynamics, to determine the conditions of motion and rest in fluid bodies, and is divided into four parts, according as fluids are incompressible or elastic, and according as their equilibrium or their motion is considered.]—*Playfair's* "*Natural Philosophy.*"

† From the Greek *udor* ("Υδωρ) water, and *stasis* (Στάσις) standing. [By hydrostatics is commonly understood that part of natural philosophy which considers the equilibrium and pressure of fluids in general, though that word seems to be restrained to water, which is a particular fluid, and the most obvious of all fluids; and by means of which we shall make out most of our following conclusions.]—*Cotes's Hydrostatical and Pneumatical Lectures.*

‡ From the Greek *udor* ("Υδωρ) water, and *aulos* (Αὐλὸς) a pipe or tube. [Hydraulics is that branch of natural philosophy which treats of the motions of liquids, the laws by which they are regulated, and the effects they produce.]—*Brande's* "*Dictionary of Science, Literature, and Art.*"

A variation of this experiment will throw much light upon the subject. Instead of using one let there be two liquids, of which the specific gravities are different. Put one in one of the branches of the tube, *a b c*, Fig. 51, and the other in the other. Let the liquids be quicksilver and water. It will be found, under these circumstances, that the water does not press the quicksilver up to its own level, but that, for every thirteen and a half inches vertical height that it has in one of the branches the quicksilver has one inch in the other. Of course, as they communicate through the horizontal branch, *b*, the quicksilver must press against the water as strongly as the water presses against it; if it did not, movement would ensue. And such experiments, therefore, prove that it is the principle of equality of pressures which determines liquids to seek their own level.

From this it therefore appears, that a liquid in a vessel not only exerts a pressure upon the bottom in the direction in which gravity acts, but also laterally and upward.

From what was proved by the experiment represented in Fig. 50, it follows that these pressures are by no means necessarily as the mass, but in proportion to the vertical height. If one hundred drops of water be arranged in a vertical line, the lower one will exert on the surface on which it rests a pressure equal to the weight of the whole. And from such considerations we deduce the general rule for estimating the pressure a liquid exerts upon the base of a vessel. "Multiply the height of the fluid by the area of the base on which it rests, and the product gives a mass which presses with the same weight."

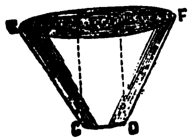

Fig. 52.

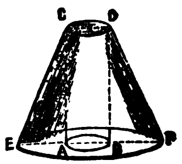

Fig. 53.

Thus, in a conical vessel, E C D F, Fig. 52, the base, C D, sustains a pressure measured by the column A B C D. For all the rest of the liquid only presses on A B C D laterally, and, resting on the sides E C and F D, cannot contribute anything to the pressure on the base, C D. But in a conical vessel, E C D F, Fig. 53, the pressure on A B is measured by A B C D, as before; but the other portions of the liquid, not resting upon the sides, press also upon the bottom, E F,—and the result, therefore, is the same as if the vessel were filled throughout to the height C D.

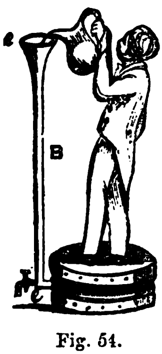

Fig. 54.

This law is nothing more than an expression of the fact that the actual pressure of a liquid is dependent on its vertical height and the area of its base. Its applications give rise to some singular results. Thus, the hydrostatic bellows consists of a pair of boards, A, Fig. 54, united together by leather, and from the lower one there rises a tube *e* B *e*, ending in a funnel-shaped termination, *e*. If heavy weights are put upon the upper board, or a man stands upon it, by pouring water down the tube the weight can be raised. It is immaterial how slender the tube, and, therefore, how small the quantity of water it contains, the total pres-

sure resulting depends on the area of the bellows-boards, multiplied by the vertical height of the tube.

Theoretically, therefore, it appears that a quantity of water, however small, can be made to lift a weight however great—a principle sometimes spoken of as the HYDROSTATIC PARADOX.

But liquids exert a pressure against the sides, as well as upon the bases of the containing vessel—the force of that pressure depending on the height. The law for estimating such pressure is, "the horizontal force exerted against all the sides of a vessel is found by multiplying the sum of the areas of all the sides into a height equal to half that at which the liquid stands."

When bodies are sunk in a liquid, the liquid exerts a pressure which depends conjointly on the surface of the solid and the depth to which its centre is sunk. Thus, if into a deep vessel of water we plunge a bladder, to the neck of which a tube is tied, the bladder and part of the tube being filled with coloured water, it will be seen, as the bladder is sunk, that the coloured water rises in the tube.

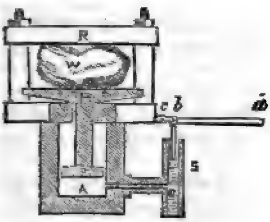

Fig. 55.

A pressure exerted against one portion of a liquid is instantly communicated throughout the whole mass, each particle transmitting the same pressure to those around. A striking illustration of this is seen when a Prince Rupert's drop is broken in a glass of water, the glass being instantly burst to pieces.

Bramah's press, or the hydrostatic press, is an illustration of the principle developed in this lecture—that every particle of a fluid transmits the pressure it receives, in all directions, to those around. It consists of a small metallic forcing-pump, *a*, Fig. 55, in which a piston, *s*, is worked by a lever, *c b d*. This little pump communicates with a strong cylindrical reservoir, A, in which a water-tight piston, S, moves, having a stout flat head, P, between which and a similar plate, R, supported in a frame, the substance to be compressed, W, is placed. The cylinder, A, and the forcing-pump, with the tube communicating between them, are filled with water, the quantity of which can be increased by working the lever, *d*. Now it is obvious that any force, impressed upon the surface of the water in the small tube, *a*, will, upon the principles just described, be transmitted to that in A, and the piston, S, will be pushed up with a force which is proportional to its area, compared with that of the piston of the little cylinder, *a*. If its area is one thousand times that of the little one, it will rise with a force one thousand times as great as that with which the little one descends—the motive force applied at *d*, moreover, has the advantage of the leverage, in proportion as *c d* is greater than *c b*. On these principles it may be shown that a man can, without difficulty, exert a compressing force of a million of pounds by the aid of such a machine of comparatively small dimensions.

CHAPTER XI.

SPECIFIC GRAVITY.

Definition of the term—The Standards of Comparison—Method for Solids—Case when the Body is Lighter than Water—Method for Liquids by the Thousand-Grain Bottle—Effects of Temperature—Standards of Temperature—Other Methods for Liquids—Method for Gases—Effects of Temperature and Pressure—The Hydrometer or Arëometer.

By the specific gravity of bodies we mean the proportion subsisting between absolute weights of the same volume. Thus, if we take the same volume of water and copper, one cubic inch of each, for example, we shall find that the copper weighs 8·6 times as much as the water: and the same holds good for any other quantity, as ten cubic inches or one cubic foot. When of the same volume the copper is always 8·6 times the weight of the water.

Specific gravity is, therefore, a relative affair. We must have some substance with which others may be compared. The standard which has been selected for solids and liquids is water; that for gases and vapours, atmospheric air.

When we speak of the specific gravity of a substance which is of the liquid or solid kind, we mean to express its weight compared with the weight of an equal volume of water. Thus, the specific gravity of mercury is 13·5; that is to say, a given volume of it would weigh 13·5 times as much as an equal volume of water.*

A TABLE OF THE MEAN SPECIFIC GRAVITIES OF VARIOUS BODIES, AT A TEMPERATURE OF 60° FAHRENHEIT.

1. Solids.	
Platina, laminated	22·069
—— purified	19·500
Gold, cast	19·253
—— hammered	19·361
—— standard, 22 carats	17·486
Mercury, solid	13·610
Lead, cast	11·352
Silver, hammered	10·510
—— cast	10·474
Sulphuret of Mercury	10·000
Bismuth, cast	9·822
Copper, cast	9·788
Brass, wire	8·544
—— cast	8·395
Steel, soft	7·833
—— tempered	7·816
Nickel, cast	7·807
Iron, malleable	7·788
—— cast	7·207
Tin, cast	7·291
Zinc, cast	7·190
Manganese	6·850
Antimony	6·702
Arsenic	5·8843
Natural Magnet	4·800
Ponderous Spar (Sulphate of Barytes)	4·430
Oriental Ruby	4·283
Bohemian Garnet	4·188
Oriental Topaz	4·010
Brazilian Topaz	3·536
—— Ruby	3·531
Diamond	3·521
Fluor Spar	3·181
Marble, Parian white	2·837
—— Carrara white	2·716
Rock Crystal	2·653
Flint	2·594
Selenite (Sulphate of Lime)	2·322
Common Salt	2·130
Sulphur, native	2·033
Plumbago, or Black Lead	1·860
Ivory	1·820
Phosphorus	1·770
Lignum Vitæ	1·327
Coal	1·270
Jet	1·238
Coral	1·210
Ebony	1·177
Oak, heart of, 60 years felled	1·170
Pitch	1·150
Rosin	1·100
Mahogany	1·063
Amber	1·040
Brazil Wood	1·031
Beeswax	0·955
Butter	0·940
Logwood	0·913
Ash (dry)	0·838
Plumtree (dry)	0·828
Elm (dry)	0·801
Oak (dry)	0·800
Yew	0·760
Crabtree	0·700
Beech (dry)	0·700
Walnut-tree (dry)	0·650
Cedar	0·613
Willow	0·585
Fir	0·580
Poplar	0·383
Cork	0·270
2. Fluids.	
Mercury, fluid	13·568
Oil of Vitriol (Sulphuric Acid)	1·840
Nitric Acid (highly concentrated)	1·583
—— (Aqua Fortis)	1·271
Honey	1·450
Hydrochloric Acid (Spirit of Salt)	1·194
Human Blood	1·054
Milk, Cows'	1·032

Sea-water	1·030	3. GASES AND VAPOURS, THAT OF ATMOSPHERIC AIR BEING 1.		Hydriodic Acid	4·340
Serum of Human Blood	1·030			Hydrogen	0·069
Ale	1·028			Nitric Oxide	1·041
Vinegar	1·026	Atmospheric Air	1·000	Nitrogen	0·972
Tar	1·015	Ammoniacal	0·590	Nitrous Acid	2·638
Water	1·000	Carbonic Acid	1·527	Nitrous Oxide	1·521
Distilled Water	0·993	——— Oxide	0·972	Oxygen	1·111
Oil of Aniseed	0·986	Carburetted Hydrogen	0·972	Phosphuretted Hydrogen	0·902
Linseed Oil	0·932	Chlorine	2·500	Sub-carburetted Hydrogen	0·555
Brandy	0·927	Chlorocarbonous Acid	3·472	Sub-phosphuretted Hydrogen	0·972
Proof Spirit	0·916	Chloroprussic Acid	2·152	Sulphuretted Hydrogen	0·180
Olive Oil	0·913	Cyanogen	1.805	Sulphurous Acid	2·222
Oil of Turpentine	0·870	Enchlorine	2·440		
Alcohol	0·794	Fluoboric Acid	3·371		
W. T. K.		Fluosilicic Acid	3·632		

Brande's "Dictionary of Science, Literature, and Art," 1842, p. 529.

Apparently the simplest way for the determination of specific gravities of solids, would be to form samples of a uniform volume; as, for instance, one cubic inch. Their absolute weight, as determined by the balance, would be their specific gravities.

But, in practice, so many difficulties would be encountered in such a process, that its results would not furnish us with accurate information, whereas the principles of hydrostatics furnish us with far more accurate means for resolving such problems.

To determine the specific gravity of a solid body, it is to be weighed first in air and then in water.* In the latter instance it will weigh less than in the former, because it displaces a quantity of the water equal to its own volume, and this deficit in weight is the weight of the water so displaced. The weight in air and the loss in water being thus determined, to find the specific gravity, "Divide the weight in air by the loss in water, and the quotient is the specific gravity."

"If the body be lighter than water, there must be affixed to it some substance sufficiently heavy to sink it, the weight of which, and also its loss of weight in water, are previously known. Deduct this weight from the loss of the bodies when immersed together, and divide the absolute weight of the light body by the remainder; the quotient gives the specific gravity."

For the determination of the specific gravity of liquids several methods

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* To find the specific gravity of bodies.

1. *If it be a solid body, heavier than water,* weigh it exactly, first in air and then in water, or some fluid whose specific gravity you know; and let the absolute weight of the body = A, the weight of the body in water, &c. = B, the specific gravity of water, &c. = C, the specific gravity of the body = D. Then will $D = \frac{A}{A-B} C$, the specific gravity of the body.

2. *For a solid body, lighter than water.* Take any piece of metal, and tie it to a piece of the light body, so that the compound may sink in water; and putting A, C, D, as in No. 1, and E = weight of the metal in water, F = weight of the compound in water. Then, $D = \frac{AC}{A+E-F}$ the specific gravity of the light body.

3. *For a fluid.* Take a solid body of known specific gravity, which will sink in the fluid, and putting the same letters as in No. 1; then will $C \frac{A-B}{A} D$, the specific gravity of the fluid.

"*The Principles of Mechanics,*" by WILLIAM EMERSON, with Notes by G. A. SMEATON.

may be resorted to. One of the most simple is by the thousand-grain bottle. This consists of a light glass flask, the stopper of which is also of glass, with a fine perforation through it. When the bottle is filled with distilled water, and the stopper inserted in its place, any excess of liquid is forced through the perforation, and the bottle, on being weighed, should be found to contain one thousand grains of the liquid exactly.

If any other liquid be in like manner placed in this bottle, by merely ascertaining its weight we at once determine its specific gravity. Thus, if it be filled with oil of vitriol or muriatic acid, it will be found to hold 1,845 grains of the former, and 1,210 of the latter. These numbers, therefore, represent the specific gravities of the bodies respectively.

This instrument enables us to illustrate, in a very satisfactory manner, the effect of temperature on specific gravity. It has been said that the thousand-grain bottle is so called from its containing precisely one thousand grains of water; but very superficial consideration satisfies us that this can only be the case at a particular temperature. Suppose the bottle is of such dimensions that at 60° Fahrenheit it contains exactly one thousand grains; if we raise its temperature to 70° Fahrenheit, the water will expand, or if we lower it to 50° Fahrenheit it will contract, exactly as if it were a liquid in a thermometer. It is, therefore, very clear that temperature must always enter into these considerations, and that before we can express the relation of weight between any substance, whether solid or liquid, and that of an equal volume of water, we must specify at what particular temperature the experiment was made. For many purposes 60° Fahrenheit is selected, and for others 39½° Fahrenheit, which is the temperature of the maximum density of water.

There is a second method by which the specific gravity of fluids may be known. It is to weigh a given solid (as a mass of glass) in the fluids to be tried, and determine the loss of weight in each case. Inasmuch as the solid displaces its own volume of the different liquids, the losses it experiences when thus weighed will be proportional to the specific gravities. The following rule, therefore, applies: "Divide the loss of weight in the different liquids by the loss of weight in water, and the quotients will give the specific gravities of the liquids under trial."

For the determination of the specific gravities of gases a plan analogous in principle to that of the thousand-grain bottle is resorted to. A light glass flask, exhausted of air, is attached by means of the stop-cocks to the jar, containing the gas to be tried. This gas been passed through a drying-tube by means of a bent pipe into the jar over mercury. On opening the stop-cock the gas flows in, and its weight may then be determined by the balance.

From the greater dilation of gases by heat, all that has just been said in relation to the effect of temperature on specific gravity applies here still more strongly. It is to be recollected that this form of bodies is, compared with atmospheric air, taken as the standard.

For gases another disturbing agency beside temperature intervenes—it is pressure. Atmospheric pressure is incessantly varying, and the densities of gases vary with it. It is not alone the thermometer, but also the barometer, which must be consulted, and the temperature and pressure both specified. Besides, great care must be taken, in transferring the gas from the jars in which it is contained, that it is not subjected to any accidental pressures in

the apparatus itself, and that the flask in which it is weighed is not touched by the hands, or submitted to any other warming or cooling influences.

[The determination of the specific gravity of gaseous substances is an operation of much greater delicacy. From the extreme lightness of gases, it would be inconvenient to compare them with an equal bulk of water, and, therefore, atmospheric air is taken as the standard of comparison. The first step of the process is to ascertain the weight of a given volume of air. This is done by weighing a very light glass flask, furnished with a stop-cock, while full of air; and then weighing it a second time, after the air has been withdrawn by means of the air-pump. The difference between the two weights gives the information required. According to the observation of Prout, 100 cubic inches of *pure and dry* atmospheric air, at the temperature of 60°, and when the barometer stands at 30 inches, weigh 31·0117 grains. By a similar method the weight of any other gas may be determined, and its specific gravity be inferred accordingly. For instance, suppose 100 cubic inches of oxygen gas are found to weigh 34·109 grains, its specific gravity will be thus deduced; as 31·0117 : 34·109 : : 1 (the specific gravity of air) : 1·1025, the specific gravity of oxygen.—"*Turner's Chemistry*" *edited by Baron Liebig.*]

For the determination of the densities of liquids there is still another method, often more convenient than the former, and very commonly resorted to; it is by the aid of instruments which pass under the name of Hydrometers or Aërometers.

The principle on which these act is, that when a body floats upon water, the quantity of fluid displaced is equal in *volume* to the volume of the part of the body immersed, and *in weight* to the weight of the whole body.

Thus, a piece of cork floating on the surface of quicksilver, water, and alcohol, sinks in them to very different depths: in the quicksilver but little, in the water more, and in the alcohol still deeper; but, in every instance, the weight of the quantity of the liquid displaced is equal to that of the cork.

It is plain, therefore, that to determine the specific gravity of a liquid, we have only to determine the depth to which a floating body will be immersed in it. The hydrometer fulfils these conditions. It consists of a cylindrical cavity of glass, A, Fig. 56, on the lower part of which a spherical bulb, B, is blown, the latter being filled with a suitable quantity of small shot or quicksilver. From the cylindrical portion, A, a tube, C, rises, in the interior of which is a paper scale bearing the divisions. The whole weight of the instrument is such that it floats in the liquid to be tried; and if that liquid is to be compared with water, and is lighter than water, the zero of the divided scale is toward the lower end of the paper; but if the liquid be heavier than water the zero is toward the top of the scale. Tables are usually constructed, so that, by their aid, when the point at which the hydrometer floats in a given liquid is determined in any experiment, the specific gravity is expressed opposite that number in the table.

Fig. 56.

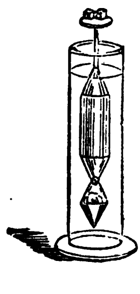
Fig. 57.

Of these scale-hydrometers we have several different kinds, according as they are to determine different liquids. Among them may be mentioned Beaumé's hydrometer, an instrument of constant use in chemistry. In the finer kinds of aërometers the weighted sphere, B, Fig. 56, forms the bulb of a delicate thermometer, the stem of which rises into the cavity, A. This enables us to determine the temperature of the liquid at the same time with its specific gravity.

Nicholson's gavimeter is a hydrometer which enables us to determine the density either of solids or liquids. It is represented by Fig. 57.

CHAPTER XII.

HYDROSTATIC PRESSURES AND FORMATION OF FOUNTAINS.

Fundamental Fact of Hydrostatics—holds also for Gases—Illustrations of Upward Pressure—Determination of Specific Gravities of Liquids on these principles—Theory of Fountains—Cause of Natural Springs—Artesian Wells.

THE fundamental fact in hydrostatics thus appears to be, that as each atom of a liquid yields to the influence of gravity without being restrained by any cohesive force, all the particles of such a mass must press upon those which are immediately beneath them, and, therefore, the pressure of a liquid must be as its depth.

The same fact has already been recognised for elastic fluids, in speaking of the mechanical properties of the earth's atmosphere, which, for this very reason, and also from the circumstance that it is a highly compressible body, possesses different densities at different heights. The lower regions have to sustain or bear up the weight of all above them; but as we go higher and higher this weight becomes less and less, until at the surface it ceases to exist at all.

We have already shown, from the nature of a fluid, such pressures are propagated equally in all directions, upward and laterally, as well as downward. This important principle deserves, however, a still further illustration from the consequences we have now to draw from it. Let a tube of glass, *a b*, Fig. 58, have its lower end, *b*, closed with a valve slightly weighted and opening upward, the end, *a*, being open. On holding the tube in a vertical position, the valve is kept shut by its own weight. But if we depress it in a vessel of water, as soon as a certain depth is reached the *upward* pressure of the water forces the valve, and the tube begins to fill. Still further, if before immersing the tube we fill it to the height of a few inches with water, we shall find that it must now be depressed to a greater depth than before, because the downward pressure of the included water tends to keep the valve shut.

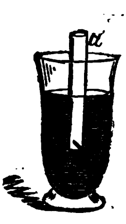

Fig. 58.

From the same principles it follows, that whenever a liquid has freedom of motion, it will tend to arrange itself, so that all parts of its surface shall

be equi-distant from the centre of the earth. For this reason the surface of water in basins, and other reservoirs of limited extent, is always in a horizontal plane; but when those surfaces are of greater extent, as in the case of lakes and the sea, they necessarily exhibit a rounded form, conforming to the figure of the earth. It is also to be remembered that, when liquids are included in narrow tubes, the phenomena of capillary attraction disturb both their level and surface-figure.

Fig. 59.

All liquids, therefore, tend to find their own level. This fact is well illustrated by the instrument, Fig. 59, consisting of a cylinder of glass, *a*, connected by means of a horizontal branch with the tube *b*, which moves at a tight joint at *c*. By this joint, *b* can be set parallel to *a*, or in any other position. If *a* is filled with water to a given height, the liquid immediately flows through the horizontal connecting-pipe, and rises to the same height in *b* that it occupies in *a*. Nor does it matter whether *b* be parallel to *a*, or set at any inclined position; the liquid spontaneously adjusts itself to an equal altitude.

The same liquid always occupies the same level. But when in the branches of a tube we have liquids, the specific gravities of which are different, then, as has already been stated in Chapter X., they rise to different heights. The law which determines this is, "*The heights of different fluids are inversely as their specific gravities.*" If, therefore, in one of the branches of a tube, *a b*, Fig. 60, some quicksilver is poured so as to rise to a height of one inch, it will require in the other tube, *b c*, a column of water $13\frac{1}{2}$ inches long to equilibrate it, because the specific gravities of quicksilver and water are as $13\frac{1}{2}$ to 1.

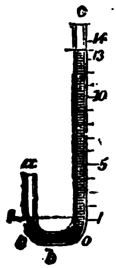

Fig. 60.

A very neat instrument for illustrating these facts is shown in Fig. 61. It consists of two long glass tubes, *a b*, which are connected with a small exhausting syringe, *c*, their lower ends being open dip into the cups *w á*, in which the liquids whose specific gravities are to be tried are placed. Let us suppose they are water and alcohol. The syringe produces the same degree of partial exhaustion in both the tubes, and the two liquids, equally pressed up by the atmospheric air, begin to rise. But it will be found that the alcohol rises much higher than the water—to a height which is inversely proportional to its specific gravity.

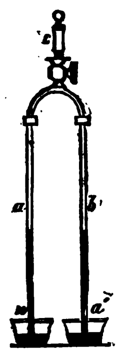

Fig. 61.

When in the instrument, Fig. 59, we bend the tube *b* upon its joint, so that its end is below the water-level in *a*, the liquid now begins to spirt out; or if, instead of the jointed tube, we have a shorter tube, C *e* D, Fig. 62, proceeding from the reservoir A B, the water spouts from its termination and forms a fountain, E F, which rises nearly to the same height as the water-level. The resistance of the air and the descent of the falling drops

shorten the altitude to which the jet rises to a certain extent. On the top of the fountain a cork ball, G, may be suspended by the playing water.

Fig. 62.

The same instrument may be used to show the equality of the vertical and lateral pressures at any point. For let the tube D E, be removed so as to leave a circular aperture at *e*; also let C be a plug closing an aperture in the bottom of exactly the same size as *e*,—now, if the reservoir, A B, be filled to the height *g*, and kept at that point by continually pouring in water, and the quantities of liquid flowing out through the lateral aperture *e*, and the vertical one, C, be measured, they will be found precisely the same, showing therefore the equality of the pressures; but if an aperture of the same size were made at *f*, the quantity would be found correspondingly less.

It is upon these principles that fountains often depend. The water in a reservoir at a distance is brought by pipes to the jet of the fountain, and there suffered to escape. The vertical height to which it can be thrown is as the height of the reservoir, and by having several jets variously arranged in respect of one another, the fountain can be made to give rise to different fanciful forms, as is the case with many public fountains.

A simple method of exhibiting the fountain is shown in Fig. 63. A jar, G, is filled with water, and a tube, bent as at *a b c*, is dipped in it. By sucking with the mouth at *a*, the water may be made to fill the tube, and then, on being left to itself, will play as a fountain.

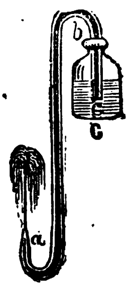

Fig. 63.

On similar principles we account for the occurrence of springs, natural fountains, and artesian wells. The strata composing the crust of the earth are, in most cases, in positions inclined to the horizon. They also differ very greatly in permeability to water—sandy and loamy strata readily allowing it to percolate through them, while its passage is more perfectly resisted by tenacious clays. On the side of a hill, the superficial strata of which are pervious, but which rest on an impervious bed below, the rain water penetrates, and being guided along the inclination, bursts out on the sides of the hill or in the valley below, wherever there is a weak place, as where its vertical pressure has become sufficiently powerful to force a way. This constitutes a common spring.

The general principle of the artesian or overflowing wells is illustrated in Fig. 64. Let *b' b c d*, be the surface of a region of country the strata of which, *b' b*, and *d*, are more or less impervious to water, while the intermediate one, *c*, of a sandy or porous constitution, allows it a freer passage. When in the distant sandy country, at *c*, the rain falls, it percolates readily, and is guided by the resisting stratum *d*. Now if

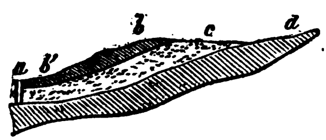

Fig. 64.

at *a* a boring is made deep enough to strike into *c*, or near to *d*, on the principle which we have been explaining, the water will tend to rise in that boring to its proper hydrostatic level, and therefore, in many instances, will overflow at its mouth. The region of country in which this water originally fell may have been many miles distant.

[London stands in a hollow, of which the first or innermost layer is a basin of clay, placed over chalk, and on boring through the clay (sometimes of 300 feet in thickness) the water issues, and in many places rises considerably above the surface of the ground, showing that there is a higher source or level somewhere.—*Dr. Arnott's "Elements of Physics,"* 3*rd edition, page* 275.]

It follows, from the action of gravity on liquids, that if we have several which differ in specific gravity in the same vessel, they will arrange themselves according to their densities. Thus, if into a deep jar we pour quicksilver, solution of sulphate of copper, water, and alcohol, they will arrange themselves in the order in which they have been named.

CHAPTER XIII.

OF FLOWING LIQUIDS AND HYDRAULIC MACHINES.

Laws of the Flowing of Liquids—Determination of the Quantity Discharged—Contracted Vein—Parabolic Jets—Relative Velocity of the parts of Streams—Undershot, Overshot, and Breast-Wheels—Common Pump—Forcing-Pump—Vera's Pump—Chain-Pump.

If a liquid, the particles of which have no cohesion, flows from an aperture in the bottom of its containing vessel, the particles so descending fall to the aperture with a velocity proportional to the height of the liquid.

The force and velocity with which a liquid issues depend, therefore, on the height of its level—the higher the level the greater the velocity.

As the pressures are equal in all directions, and as it is gravity which is the cause of the flow, "The velocity which the particles of a fluid acquire when issuing from an orifice, whether sideways, upward, or downward, is equal to that which they would have acquired in falling perpendicularly from the level of the fluid to that of the orifice."

When a liquid flows from a reservoir which is not replenished, but the level of which continually descends, the velocity is uniformly retarded; so that an unreplenished reservoir empties itself through a given aperture in twice the time which would have been required for the same quantity of water to have flowed through the same aperture, had the level been continually kept up to the same point.

The theoretical law for determining the quantity of water discharged from an orifice, and which is, that "the quantity discharged in each second may be obtained by multiplying the velocity by the area of the aperture," is not found to hold good in practice—a disturbance arising from the adhesion of the particles to one another, from their friction against the aperture, and from the formation of what is designated "the contracted vein." For when water flows through a circular aperture in a plate, the diameter of the

issuing stream is contracted, and reaches its minimum dimensions at a distance about equal to that of half the diameter of the aperture. This effect arises from the circumstance that the flowing water is not alone that which is situated perpendicularly above the orifice, but the lateral portions likewise move. These, therefore, going in oblique directions, make the stream depart from the cylindrical form, and contract it, as has been described.

By attachment of tubes of suitable shapes to the aperture, this effect may be avoided, and the quantity of flowing water greatly increased. A simple aperture and such a tube being compared together, the latter was found to discharge half as much more water in the same space of time.

As the motion of flowing liquids depends on the same laws as that of falling solids, and is determined by gravity, it is obvious that the path of a spouting jet, the direction of which is parallel or oblique to the horizon, will be a parabola; for, as we shall hereafter see, that is the path of a body projected under the influence of gravity in vacuo. When a liquid is suffered to escape in a horizontal direction through the side of a vessel, it may be easily shown to flow in a parabolic path. The maximum distance to which a jet can reach on a horizontal plane is, when the opening is half the height of the liquid.

[In consequence of the motion of water, or other liquids, being subject to the same laws as falling bodies, it is evident that the velocity and quantity of water discharged at various depths in rivers would be as the square roots of those depths, provided various mechanical causes did not exist to check its force. Let A B C D represent a tank of water, from which a channel, B D F I, slopes considerably. It will be found that the lower part of the water at D has a velocity as the square root of the depth B D; the water at F flows with a velocity proportioned to the square root of the depth E F; and the water at I as the square root G I. The top water at H has only a velocity equal to that of the bottom water at F, because it is the same depth from the line of level A B G; and, therefore, by the same rule, we may arrive at the velocity of any part of the channel.

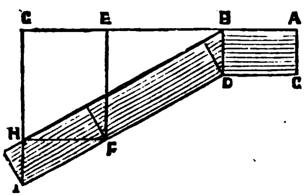

Fig. 65.

[A very slight declivity suffices to give the running motion to water. Three inches per mile, in a smooth, straight channel, gives a velocity of about three miles per hour. The Ganges, which gathers the waters of the Himalaya mountains, the loftiest in the world, at 1,800 miles from its mouth, is only 800 feet above the level of the sea—that is, about twice the height of St. Paul's church in London; and to fall these 800 feet in its long course, the water requires more than a month. The great river Magdalena, in South America, running for 1,000 miles between two ridges of the Andes, falls only 500 feet in all that distance. Above the commencement of the thousand miles, it is seen descending in rapids and cataracts from the mountains.—*Dr. Arnott's "Elements of Physics," page* 260.]

To measure the velocity of flowing water, floating bodies are used: they drift, immersed in the stream under examination. A bottle partly filled,

with water, so that it will sink to its neck, with a small flag projecting answers very well; or the number of revolutions of a wheel accommodated with float-boards may be counted.

In any stream, the velocity is greatest in the middle (where the water is deepest), and at a certain distance from the surface. From this point it diminishes toward the banks. Investigations of this kind are best made by Pictot's stream-measurer, Fig. 66. It consists of a vertical tube, with a trumpet-shaped extremity, bent at a right angle. When plunged in motionless water the level in the tube corresponds with that outside, but the impulse of a stream causes the water to rise in the tube until its vertical pressure counterpoises the force.

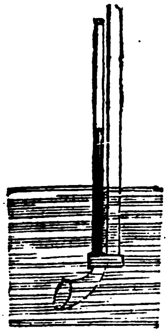

Fig. 66.

The force of flowing water is often employed for various purposes in the arts. We have several different kinds of water-wheels, as the undershot, the overshot, and the breast-wheel. The first of these consists of a wheel or drum revolving upon an axis, and on the periphery there are placed float-boards, *a b c d e*, &c. It is to be fixed so that its lower floats are immersed in a running stream or tide, and is driven round by the momentum of the current.

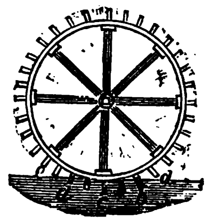

Fig. 67.

[It is obvious that we may make the diameter of an undershot wheel as great as we please; and that, the greater the diameter, the larger will be the gain of power. But in this, as in all previous instances, what is gained in power is lost in velocity; since a given amount of movement in the water, which would carry a wheel of 12 feet in diameter through a whole revolution, will only carry a wheel of 24 feet through half a revolution.—*Dr. Carpenter's "Mechanical Philosophy," page* 262.]

The overshot-wheel, in like manner, consists of a cylinder or drum, with

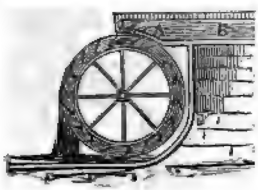

Fig. 68

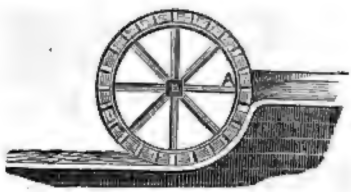

Fig. 69.

a series of cells or buckets, so arranged that the water which is delivered by a trough, A B, on the uppermost part of the wheel, may be held by the descending buckets as long as possible. It is the weight of this water that gives motion to the wheel on its axis.

The breast-wheel, in like manner, consists of a drum working on an axis,

and having float-boards on its periphery. It is placed against a wall of a circular form, and the water brought to it fills the buckets at the point A, and turns the wheel, partly by its momentum, and partly by its weight.

The most advantageous diameter of the breast-wheel will depend, like that of the overshot-wheel, upon the height of the fall. It is obvious that the water does not act equally in moving the wheel during the whole of its descent: for, as the power produced by its weight always acts in lines perpendicular to the earth's surface, its action at A is in the direction A *a*, and therefore the length of leverage is only C *c*. By the time that the wheel has moved round, so that the weight is at B, it will act in the direction B *b*, and therefore with the lever power C *d*; and when it has arrived at D, it will act with the power of the full radius D C. It is obvious that no weight of water at E will have any influence in turning the wheel, since its pressure is in the downward direction, E F; but as soon as it is acting, to the least degree, on one side of this, it will begin to exert a power which continually increases until it reaches D, after which it will diminish in the same proportion.—*Dr. Carpenter's "Mechanical Philosophy," page* 263.]

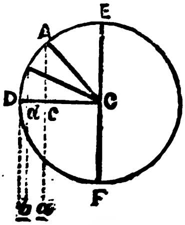

Fig. 70.

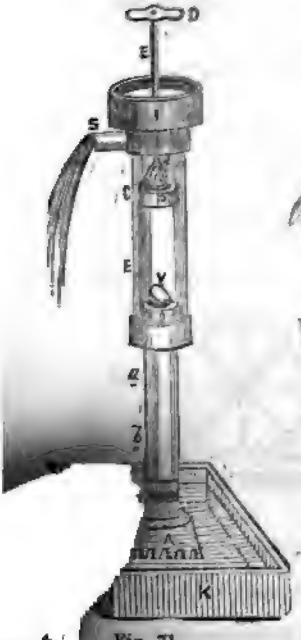

Fig. 71.

Fig. 73.

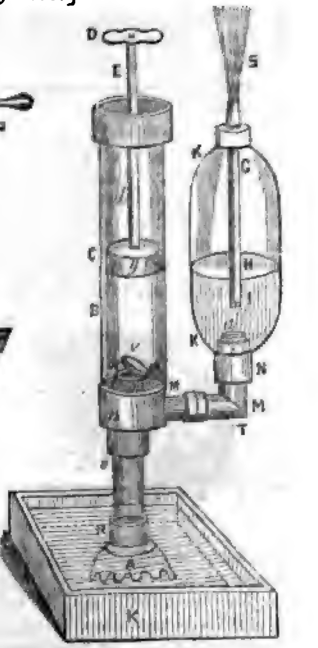

Fig. 72.

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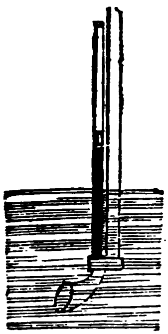

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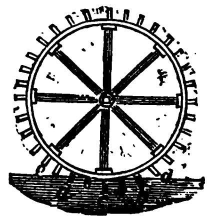

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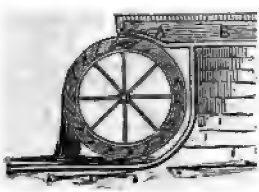
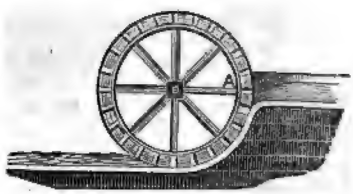


Fig. 68



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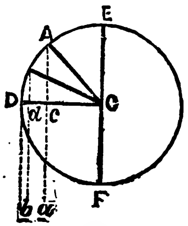


Fig. 70.

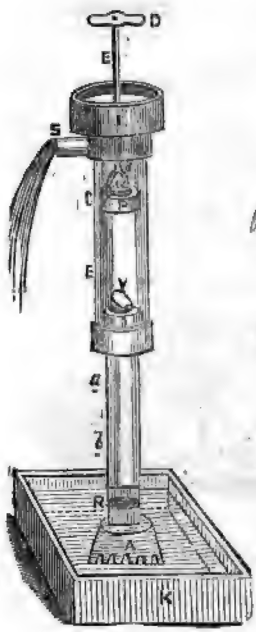


Fig. 71.

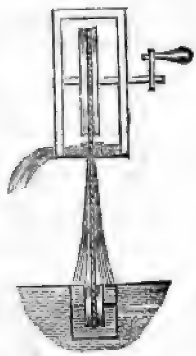


Fig. 73.

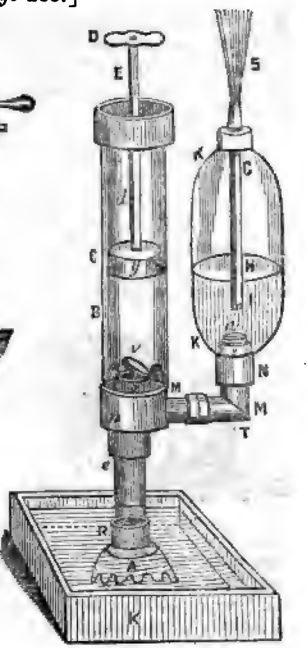


Fig. 72.

Of these three forms the overshot-wheel is the most powerful.

There are a great many contrivances for the purpose of raising water to a higher level. These constitute the different varieties of pumps.

The common pump is represented in Fig. 71. It consists of three parts: the suction-pipe, the barrel, and the piston. The suction-pipe, *a b*, is of sufficient length to reach down to the water, A, proposed to be raised from the reservoir, R. The barrel, C B, is a perfectly cylindrical cavity, in which the piston, P, moves, air-tight, up and down, by the rod, *d*. It is commonly moved by a lever, but in the figure a rod and handle, D E, are represented. On one side is the spout, S. At the top of the suction-pipe, at O, there is a valve, *r*, and also one on the piston, at *c*. They both open upward. When the piston is raised from the bottom of the barrel, and again depressed, it exhausts the air in the suction-pipe, and the water rises from the reservoir, pressed up by the atmosphere. After a few movements of the piston the barrel becomes full of water, which, at each successive lift, is thrown out of the spout, S. The action of this machine is readily understood, after what has been said of the air-pump, which it closely resembles in structure.

In the forcing-pump the suction-pipe, *e* R, is commonly short, and the piston, *g*, has no valve. On the box at O there is a valve, *r*, as in the former machine, and when the piston is moved upward in the barrel, C B, by the handle, E, and rod, D *d*, the water, A, rises from the reservoir, R, and enters the barrel. During the downward movement of the piston the valve, *r*, shuts, and the water passes by a channel round *m*, through the lateral pipe, M T M N, into the air-vessel, K K. The entrance to this air-vessel, at P, is closed by a valve, *a*, and there proceeds from it a vertical tube, H G, open at both ends. After a few movements of the piston, the lower end, I, of this tube becomes covered with water, and any further quantity now thrown in compresses the air in the space, H G, which, exerting its elastic force, drives out the water in a continuous jet, S. The reciprocating motion of the piston may, therefore, be made to give rise to a continuous and unintermitting stream by the aid of the air-vessel, K K.

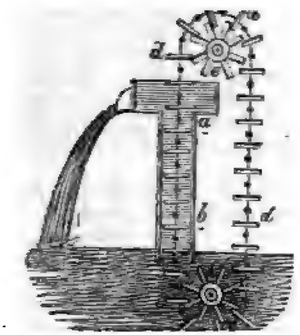


Fig. 74.

Among other hydraulic machines may be mentioned Vera's pump, more, however, from its peculiar construction than for any real value it possesses. It consists of a pair of pulleys, over which a rope is made to run rapidly; the lower one is immersed in the water to be raised. By adhesion a portion of the water follows the rope in its movements, and is discharged into a receptacle placed above. (Fig 73.)

The chain-pump consists of a series of flat-plates, *d*, held together by pieces of metal, so arranged that, by turning an upper wheel, *e*, the whole chain is made to revolve, on one side ascending and on the other descending and passing over a lower wheel. As the flat plates pass upward they move through a trunk of suitable shape, *a b*, and therefore continually lift in it a column of water. The chain-pump requires

deep water to work in, and cannot completely empty its reservoir, but it has the advantage of not being liable to be choked.

CHAPTER XIV.

HYDRAULIC MACHINES.

Archimedes' Screw—The Syphon acts by the Pressure of Air—The Descent, Ascent, and Floating of Solids in Liquids—Quantity of Water displaced by a Floating Solid—Case where fluids of different densities are used—Equilibrium of Floating Solids.

THE screw of Archimedes is an ancient contrivance, invented by the philosopher whose name it bears, for the purpose of raising water in Egypt. It consists of a hollow screw-thread wound round an axis, upon which it can be worked by means of a handle. The lower end of this spiral tube dips in the reservoir from which the water is to be raised, and by turning the handle the water continually ascends the spire and flows out at its upper extremity.

The syphon is a tube with two branches, C E, D E, Fig. 75, of unequal length, often employed in the arts for the purpose of raising or decanting liquids. The method of using it is first to fill it, and then placing the shorter branch in the vessel, B, to be decanted, the liquid ascends to the bend and runs down the longer branch. It is obvious that this motion arises from the inequality of weight of the columns in the two branches. The long column over-balances the short one, and determines the flow; but this cannot take place without fresh quantities rising through the short branch, impelled by the pressure of the air. The syphon, therefore, is kept full by the pressure of the air, and kept running by the inequality of the lengths of the columns in its branches.

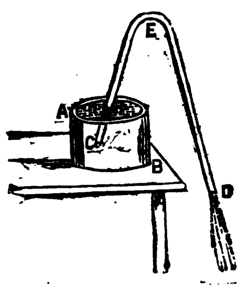


Fig. 75.

This inequality is not to be measured by the actual lengths of the glass branches themselves, but it is to be estimated by the difference of level, A, of the liquid in the vessel to be decanted and the free end, D, of the syphon.

That this instrument acts in consequence of the pressure of the air is shown by making a small one discharge quicksilver under an air-pump receiver. Its action will cease as soon as the air is removed.

By the aid of a syphon liquids of different specific gravities may be drawn out of a reservoir without disturbing one another, and those that are in the lower part without first removing those above. Upon the same principle water may be also conducted in pipes over elevated grounds.

Of the Floating of Bodies in Liquids.

A solid substance will remain motionless in the interior of a liquid mass when it is of the same specific gravity. Under these circumstances the

forces which tend to make it sink are its own weight and the weight of the column of water which is above it. But as its weight is the same as that of an equal volume of the liquid in which it is immersed, this downward tendency is counteracted and precisely equilibrated by the upward pressure of the surrounding liquid. Consequently the solid remains motionless in any position, precisely as a similar mass of the liquid itself would be.

But if the density of the immersed body is greater than that of an equal bulk of the liquid, then the downward forces preponderate over the upward pressure, and the solid descends.

If, on the other hand, the solid is lighter than an equal volume of the liquid, the upward pressure of the surrounding liquid overcomes the downward tendency, and the body rises to the surface and floats.

SPECIFIC GRAVITY.

In the act of floating, the body is divided into two regions: one is immersed in the liquid and the rest is in the air. The part which is immersed under the surface of the liquid is *such as displaces a quantity of that liquid as is precisely equal in weight to the floating solid.* This may be proved experimentally. Fill a glass, A, with water until it runs off through the spout, *a*, then immerse in it a floating body, such as a wooden ball; the ball will displace a quantity of water, which, if it be collected in the receiver, B, and weighed, will be found precisely equal to the weight of the wood.

Fig. 76.

In any fluid, a solid body will therefore sink to a depth which is greater as its specific gravity more nearly approaches that of the liquid. As soon as the two are equal, the solid becomes wholly immersed.

In fluids of different densities any floating body sinks deeper in that which has the smallest density. It will be recollected that these are the principles which are involved in the action of hydrometers. They are also applied in the case of specific-gravity bulbs, which are small glass bulbs, with solid handles, adjusted by the maker so as to be of different densities. When a number of these are put into a liquid, some will float and some will sink; but the one which remains suspended, neither floating nor sinking, has the same specific gravity as the liquid. That specific gravity is determined by the mark engraved on the bulb.

When a body floats on the surface of water it tends to take a position of stable equilibrium. The principles brought in operation here will be more fully described when we come to the study of the centre of gravity of bodies. For the present, it is sufficient to state, that stable equilibrium ensues when the centre of gravity of the floating solid is in the same vertical line as the centre of gravity of the portion of fluid displaced, and as respects position beneath it. These considerations are of great importance in the art of ship-building, and also in the right distribution of the cargo or ballast of a ship.

The principle of flotation is ingeniously applied in the ball-cock, an instrument for keeping cisterns or boilers filled with a regulated amount of water.

Thus, suppose that *m n*, Fig. 77, be the level of the water in the boiler of a steam-engine; on its surface let there float a body, B, attached by means of a rod, C, *a*, to a lever, *a c b*, which works on the fulcrum *c;* on the other side of the lever, at *b*, let there be attached, by the rod *b* V, a valve, V, allowing water to flow into the boiler, through the feed-pipe, V O. Now, as the level of the water, *m n*, in the boiler lowers through evaporation, the float, B, sinks with it, and depresses the end, *a*, of the lever; but the end, *b*, rising, lifts the valve, V, and allows the water to go down the feed-pipe; and as the level again rises in the boiler the valve, V, again shuts. Instead of a piece of wood or hollow copper-ball, a flat piece of stone, B, is commonly used: and to make it float it is counterpoised by a weight, W, on the opposite arm of the lever.

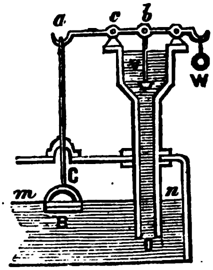


Fig. 77.

SECTION III.—Of Rest and Motion.—Mechanics.

CHAPTER XV.

MOTION AND REST.

Causes of Motion—Classification of Forces—Estimate of Forces—Direction and Intensity—Uniform and Variable Motions—Initial and Final Velocities—Direct, Rotatory, and Vibratory Motions.

All objects around us are necessarily in a condition either of motion or of rest. [Were there no motion in the universe it would be dead. It would be without the rising or setting of sun, or river-flows, or morning winds, or sound or light, or animal existence. To understand the nature and laws of the motions or changes which are going on around him, is to man of the greatest importance, as it enables him to adapt his actions to what is coming in futurity, and often to interfere so as to control and direct futurity for his special purposes.—*Dr. Arnott's "Elements of Physics."*] We shall soon find that matter has not of itself a predisposition for one or other of these states; and it is the business of natural philosophy to assign the particular causes which determine it to either in any special instance. A very superficial investigation soon puts us on our guard against deception. Things may appear in motion which are at rest, or at rest when in reality they are in motion. A passenger in a railroad-car sees the houses and trees in rapid motion, though he is well assured that this is a deception—a deception like that which occurs on a greater scale in the apparent revolution of the stars from east to west every night—the true motion not being in them, but in the earth, which is turning in the opposite direction on its axis.

If deceptions thus take place as respects the state of motion, the same holds good as respects the state of rest. On the surface of the earth even

those objects which seem to us to be quite stationary are not so in reality. Motion is described in any particular case by referring to centre objects and certain standards of velocity. A man sitting on the deck of a sailing-ship has *common* motion with the ship; if walking on the deck, he has *relative* motion to the ship; but if he be walking towards the stern, just as fast as the ship advances he is at rest relatively to the bottom or shore. A ship sailing against the tide, just as fast as the tide runs, has rest relatively both to the earth and water. *Absolute* motion is that which is relative to the whole universe, or to the space in which the universe exists. We have no means of ascertaining such: for, although we know how fast our globe whirls upon its axis, and round the sun; we have no measure of the motion of the sun himself—revolving, probably, round some more distant centre, and carrying all the planets along with him.

[Motion is called *rapid*, as that of lightning—*slow*, as that of the sun-dial shadow; both terms having reference to ordinary intermediate velocities. It is called *straight* or *rectilineal*, in the observed path of a falling body—*bent*, or *curvilinear*, in the track of a bullet shot obliquely—*accelerated*, in a stone falling to the earth—*retarded*, in a stone thrown upwards while rising to the point where it stops before again descending.—*Dr. Arnott's "Elements of Physics."*] Natural objects, as mountains and the various works of man, though they seem to maintain an unchangeable relation as respects position with all the world for centuries together, are but in a condition of RELATIVE REST. They are, of course, affected by the daily revolution of the earth on its axis, and accompany it in its annual movements round the sun. Indeed, as respects themselves, their parts are continually changing position. Whatever has been affected by the warmth of summer shrinks into smaller space through the cold of winter. Two objects which maintain their position toward each other are said to be at *relative* and *absolute rest;* but we make a wide distinction between this and *absolute rest.* All philosophy leads us to suppose that throughout the universe, there is not a solitary particle which is in reality in the latter state.

Whenever an object, from a state of apparent rest, commences to move, a cause for the motion may always be assigned. And inasmuch as such causes are of different kinds, they may be classified as primary or secondary motive powers. The primary motive powers are universal in their action. Such, for instance, as the general attractive force of matter, or GRAVITY. The secondary are transient in their effects. The action of animals, of elastic springs, of gunpowder, are examples. Of the secondary forces, some are momentary and others more permanent, some giving rise to a blow or shock, and some to effects of a continued duration.

Forces may be compared together as respects their intensities by numbers or by lines. Thus one force may be five, ten, or a hundred times the intensity of another, and that relation be expressed by the appropriate figures. In the same manner, by lines drawn of appropriate length, we may exhibit the relation of forces; and, that not only as respects their relative intensity, but also in other particulars. The *direction of motion* resulting from the application of a given force may always be represented by a straight line drawn from the point at which the motion commences toward the point to which the moving body is impelled. The point at which the force takes effect upon the body is termed the *point of application;* and the *direction of motion* is the path in which the body moves. To this special

designations are given appropriate to the nature of the case, such as curvilinear, rectilinear, &c.

Moving bodies pass over their paths with different degrees of speed. One may pass through ten feet in a second of time, and another through a thousand in the sane interval. We say, therefore, that they have different *velocities.* Such estimates of velocity are obviously obtained by comparing the spaces passed over in a given unit of time. The unit of time selected in natural philosophy is *one second.*

A moving body may be in a state of either uniform or variable motion. In the former case its velocity continually remains unchanged, and it passes over equal distances in equal times. In the latter its velocity undergoes alterations, and the spaces over which it passes in equal times are different. If the velocity is on the increase, it is spoken of as a *uniformly accelerated motion.* If on the decrease, as a *uniformly retarded motion.* In these cases we mean, by the term *initial velocity*, the velocity which the body had when it commenced moving, as measured by the space it would then have passed over in one second; and, by the *final velocity*, that which it possessed at the moment we are considering if measured in the same way. The flight of bomb-shells upward in the air is an instance of retarded motion; their descent downward of accelerated motion. The movement of the hands of a clock is an example of uniform motion.

There are motions of different kinds: 1st, direct; 2nd, rotatory; 3rd, vibratory.

1st. By direct motion we mean that in which all the parts of the whole body are advancing in the same direction with the same velocity.

2nd. By rotatory motion we imply that some parts of the body are going in opposite directions to others. The axis of rotation is an imaginary line, round which the parts of the body turn, it being itself at rest.

3rd. By vibratory movement we mean that the body which changes its original position with a motion in the opposite direction. Thus, the particles of water which form waves alternately rise and sink, and the pendulum of a clock beats backward and forward. These are examples of vibratory or oscillatory movement.

CHAPTER XVI.

OF THE COMPOSITION AND RESOLUTION OF FORCES.

Compound Motion — Equilibrium — Resultant — The Parallelogram of Forces — Case where there are more Forces than Two — Parallel Forces — Resolution of Forces — Equilibrium of three Forces — Curvilinear Motions.

WHEN several forces act simultaneously on a body so as to put it in motion, that motion is said to be compound.

In cases of compound motion, if the component or constituent forces all act in the same direction, the resulting effect will be equal to the sum of all those forces taken together.

If the constituent forces act in opposite directions, the resulting effect will be equal to their difference, and its direction will be that of the greater force. Thus, if to a knot, *a*, Fig. 78, we attach several weights, *b c*, by means of a string passing over a pulley, these weights will evidently tend to pull the knot from *a* to *e*. But if to the same knot we attach a weight, *f*, by a string passing over the pulley *g*, this tends to draw it in the opposite direction. When the weights on each side of the knot act conjointly, they tend to draw it opposite ways, and it moves in the direction of the greater force.

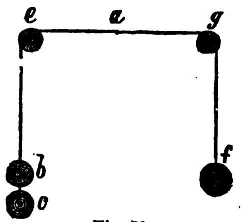


Fig. 78.

If two forces of equal intensity, but in opposite directions, act upon a given point, that point remains motionless, and the forces are said to be *in equilibrio*. When there are many forces acting upon a point in equilibrio, the sum of all those acting on one side must be equal to the sum of all the rest which act in the opposite direction.

By the *resultant* of forces we mean a single force which would represent in intensity and direction, the conjoint action of those forces.

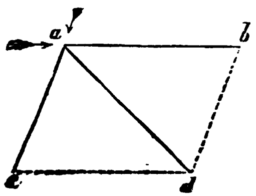


Fig. 79.

If the constituent forces neither act in the same nor in opposite directions, but at an angle to each other, their resultant can be found in the following manner:—Let *a* be the point on which the forces act; let one of them be represented in intensity and direction by the line *a b*, and the other likewise in intensity and direction by the line, *a c*. Draw the lines *b d*, *c d*, so as to complete the parallelogram, *a b c d;* draw also the diagonal, *a d*. This diagonal will be the resultant of the two forces, and will, therefore, represent their conjoint action in intensity and direction.

The operation of pairs of forces upon a point is readily understood. Thus, 1st, on a point *a*, Fig. 80, let two forces, *a b*, *a c*, act. Complete the parallelogram *a b*, *d c*, and draw its diagonal, *a d*. This line will represent in

Fig. 80 Fig. 81.

intensity and direction the resultant force. 2nd—On a point, *a*, Fig. 81, let two forces again represented in intensity and direction by the lines, *a b*, *a c*, act. Complete the parallelogram, *a b c d*, draw its diagonal, *a*, *d*, which is the resultant, as before. Now, on comparing Fig. 80 with Fig. 81, it readily appears that the resultant of two forces is greater as those forces act more nearly in the same direction, and less as those forces act more nearly in opposite directions.

Many popular illustrations of the parallelogram of forces might be cited. The following may, however, suffice. If a boat be rowed across a river when

there is no current, it will pass in a straight line from bank to bank perpendicularly; but this will not take place if there is a current; for as the boat crosses, it is drifted by the stream, and makes the opposite bank at a point which is lower according as the stream is more rapid. It moves in a diagonal direction.

On the same principles we can determine the common resultant of many forces acting on a point. Two of the forces are first taken and their resultant found. This resultant is combined with the third force, and a second resultant found. This again is combined with the fourth force, and so on, until the forces are exhausted. The final resultant represents the conjoint action of all.

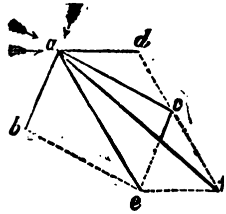


Fig. 82.

Thus, let there be three forces applied to the point *a*, represented in intensity and direction by the lines, *a b*, *a c*, *a d*, Fig. 82, respectively; if *a b* and *a c* be combined they give as their resultant *a e*, and if this resultant, *a e*, be combined with the third force, *a d*, it yields the resultant, *a f*, which, therefore, represents the common action of all three forces.

The resultant of two parallel forces applied to a line, and on the same side of it, is equal to their sum and parallel to their direction. Thus the forces *a b*, *a′ b′*, applied to the line *a a′*, give a resultant *p r*, parallel to their common direction and equal to their sum. (Fig. 83.)

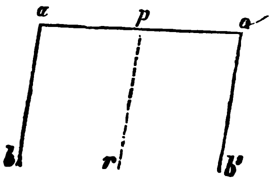


Fig. 83.

But when parallel forces are applied on opposite sides of a line, the resultant is equal to their difference, and its direction is parallel to theirs. In this, as also in the foregoing case, the point at which the resultant acts is at a distance from the point at which the two forces act, inversely proportional to their intensities. In the foregoing case this point falls between the directions of the two forces, and in the latter on the outside of the direction of the greater force.

The parallelogram of forces not only serves to effect the composition of several forces, but also the resolution of any given force; that is, to assign several forces which in their intensities and directions shall be equivalent to it. Thus let *a f*, Fig. 84, be the given force; by making it the diagonal of a parallelogram it may be resolved into its components, *a d*, *a e*; in the same manner, *a e* may be resolved into its components, *a c*, *a b*. Thus, therefore the original force is resolved into three components, *a b*, *a c*, *a d*.

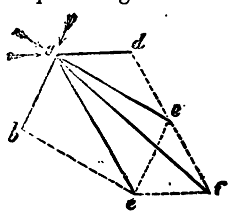


Fig. 84.

Upon similar principles it may be readily proved that two forces acting at any angle upon a point can never maintain that point in equilibrio; but three forces may; and in this instance, they will be represented in intensity and direction by the three sides of a triangle, perpendicular to their respective directions.

If two forces act upon a point in the direction of and in magnitude proportional to the sides of a parallelogram, that point will be kept in

equilibrio by a third force opposed to them in the direction of the diagonal and proportional to it. On the table, *a d*, Fig. 85, place a circular piece of paper, on which there is drawn any triangle, *a b c*, *c* coinciding with the centre of the table; and let us suppose that the sides of this triangle are, as shown in the figure, in the proportion to on another, as 2 3 4. Draw upon the paper, *c e*, parallel to *a b*, and prolong *a c* to *d*. Take three strings, making a knot at the point, *c*, and by means of the moveable pulley, *t t t*, stretch the strings over the lines *c b*, *c d*, *c e;* at the end of *c d*, suspend a weight of four pounds, at the end of *c e* one of three pounds, and at the end of *c b* one of two pounds. The knot will remain in equilibrio, proving therefore the proposition.

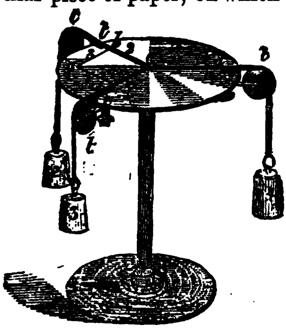


Fig. 85.

In the composition of forces power must always be lost. Thus, in this experiment, we see that a weight of three pounds and one of two pounds equipoise a weight of four pounds only.

If of two forces acting upon a point, one is momentary and the other constant, the point may move in a curve. Thus, if in Fig. 86, a shot be projected obliquely upward from a gun, it is under the action of two forces—the momentary force of the explosion of the gunpowder, and the constant effect of the attraction of the earth. It describes, therefore, a curvilinear path, *a b c*, the direction of which continually declines towards the direction of the constant force.

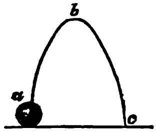


Fig. 86.

It is only when a force acts in a direction perpendicular to a body that its full effect is obtained. This is easily proved by resolving an oblique force into two others, one of which is perpendicular, and the other parallel to the side of the body acted upon. This latter force is, of course, lost.

CHAPTER XVII.

INERTIA.

Inertia a Property of Matter—Indifference to Motion and Rest—Moving Masses are Motive Powers—Determination of the Quantity of Motion—Momentum—Action and Reaction—Newton's Laws of Motion—Bohnenberger's Machine.

All bodies have a tendency to maintain their present condition, whether it be of motion or rest. It is only by the exertion of force that that condition can be changed. A mass of any kind, when at rest, resists the application of force to put it in motion, and when in motion resists any attempt to bring it to rest. This property is termed INERTIA. [It is,

therefore, clear that the action exercised upon the condition of motion of a body must depend, on the one hand, upon the intensity of the force, and, on the other, upon the degree of inertia in the body.

[The larger the quantity of matter—that is to say, the greater the mass is on which a force acts—so much greater will be the resistance it offers; and we judge of the mass of a body by the amount of resistance which it can oppose by its inertia to an accelerating or retarding force.—*Professor Müller on Physics and Meteorology, Lecture* 1.]

It is illustrated by many familar instances: thus, loaded carriages require the exertion of far more force to put them in motion than is subsequently required to keep them going, and a train of railroad cars will run for a great distance after the locomotive is detached.

Universal experience shows that inanimate bodies have no power to produce spontaneous changes in their condition. They are wholly inactive. Even when in motion they exhibit no tendency whatever to alter their state. Thus, the earth rotates on its axis at the same rate which it did thousands of years ago, and the planetary bodies pursue their orbits with an unchangeable velocity. A moving mass can neither increase nor diminish its rate of speed; for if it could do the former it must necessarily have the power spontaneously to put itself in motion if it were in a condition of rest. Nor can such a mass, if in motion, change the direction of its movements any more than it can change its velocity. Such a change of direction would imply the operation of some innate force, which of itself could have put the mass in movement.

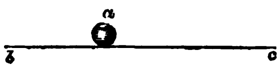


Fig. 87.

Whenever, therefore, we discover in a moving body changes in direction or changes in velocity, we at once impute them to the agency of acting forces, and not to any innate power of the moving body itself.

If an ivory ball, *a*, Fig. 87, be laid upon a sheet of paper, *b c*, on the table, and the paper suddenly pulled away, the ball does not accompany the movement, but remains in the same place on the table.

A person jumping from a carriage in rapid motion falls down, because his body, still participating in the motion of the carriage, follows its direction after his feet have struck the earth.

By the MASS of a body we mean the quantity of matter contained in it—that is, the sum of all its particles. The mass of a body depends on its volume and density.

In consequence of their inertia, masses in motion are themselves motive powers. Such a mass impinging on a second tends to set it in motion.

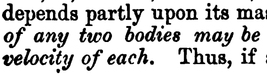


Fig. 88.

Thus, if a ball, *a*, Fig. 88, moving towards *c*, impinge upon a second ball, *b*, of equal weight, the two will move together toward *c*, with a velocity one half of that which *a* originally had. In this case, therefore, *a* has acted as a motive force upon *b*, and it is obvious that the intensity of this action must depend on the magnitude and velocity of *a*, increasing as they increase, and diminishing as they diminish. The ball, *a*, is said, therefore, to have a certain *momentum* or *moment*, which depends partly upon its mass and partly upon its velocity; and *the moments of any two bodies may be compared by multiplying together the mass and velocity of each.* Thus, if a body, A, has twice the mass of another, B, and

moves with the same velocity, the momentum of A will be twice that of B; but if A, having twice the mass of B, has only half its velocity, the moments of the two will be equal.

It is upon this principle that heavy masses moving very slowly exert a great force, and that bodies comparatively light, moving with great speed, produce striking effects. The battering-rams of the ancients, which were heavy masses moving slowly, did not produce more powerful effects than cannon-shot, which, though comparatively light, move with prodigious speed.

From the foregoing considerations, it therefore appears that the amount of motion depends neither upon the mass alone nor the velocity alone. A certain mass, A, moving with a given velocity, has a certain momentum or quantity of motion. If to A a second equal mass, B, with a similar velocity, be added, the two conjointly will, of course, possess double the momentum of the first—the mass has doubled, though the speed is the same, and therefore the quantity of motion has doubled. Again, if a certain mass, A, moves with a given speed, and a second one, B, moves with a double speed, it is obvious that this last will have twice the quantity of motion of the former—here the masses are the same, but the velocities are different. The quantity of motion or momentum which a body possesses is, therefore, obtained by multiplying together the numbers which express its mass and its velocity.

Action and *Reaction* are always equal to each other. The resistance which a given body exhibits is equal to the effect of any force operating upon it. This equality of action and reaction may be shown by an aparatus represented in Fig. 89, in which two balls of clay or putty, *a b*, are suspended by strings so as to move over a graduated arc. If one of the balls be allowed to fall upon the other, through a given number of degrees, it will communicate to it a part of its motion, and the following facts may be observed: 1st. The bodies, after collision, move on together, and therefore have the same velocity. 2nd. The quantity of motion remains unchanged, the one having gained as much as the other has lost, so that if the two are equal they will have half the velocity after impact that the moving one had when alone. 3rd. If equal, and moving in opposite directions with equal velocities, they will destroy each other's motions and come to rest. 4th. If unequal, and moving in opposite directions, they will come to rest when their velocities are inversely as their masses.

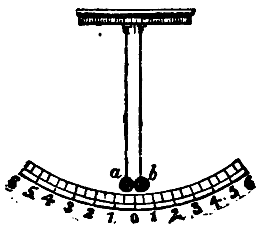


Fig. 89.

The following three propositions are called "Newton's laws of motion." They contain the results depending on inertia:—

I. Every body must persevere in its state of rest or of uniform motion in a straight line, unless it be compelled to change that state by forces impressed upon it.

II. Every change of motion must be proportional to the impressed force, and must be in the direction of that straight line in which the force is impressed.

III. Action must always be equal, and contrary to re-action; or the action of two bodies upon each other must be equal, and directed to contrary sides.

As an example of the operation of inertia, and illustrating the invariability of position of the axis of the earth during its revolution, I here describe Bohnenberger's machine. It consists of three moveable rings, A A A, Fig. 90, placed at right angles to each other, and in the smallest ring there is a heavy metal ball, B, supported on an axis, which also bears a little roller, C. A thread, being wound round this roller and any particular position being given to the axis, by quickly pulling the thread the ball may be set in rapid rotation. It is now immaterial in what position the instrument is placed; its axis continually maintains the same direction, and the ring which supports it will resist a considerable pressure tending to displace it.

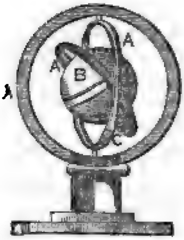


Fig. 90.

CHAPTER XVIII.

GRAVITATION.

Preliminary Ideas of Motions of Attraction—The Earth and Falling Bodies—Laws of Attraction, as respects Mass and Distance—Nature of Weight—Absolute and Specific Weight—The Plumb Line—Convergence of such Lines towards the Earth's Centre—Action of Mountain Masses.

ALL material substances exert upon each other an attractive force. To this the designation of Gravity, or Gravitation, has been given. It was the great discovery of Sir Isaac Newton, that the same force which produces the descent of a stone to the ground holds together the planets and other celestial bodies.

To obtain a preliminary idea of the nature and operation of this force, let us suppose that two balls of equal weight be placed in presence of each other, and under such circumstances that no extraneous agency supervene to interfere with their mutual action. Under these circumstances, all the phenomena of Nature prove that the two balls will commence moving toward each other with equal speed, their velocity continually increasing until they come in contact. Inasmuch, therefore, as their masses are equal, and their velocities equal, the quantities of motion they respectively possess will also be equal, as is proved in Chapter 17.

Again, let there be other balls situated as before, but let one of them, B, be twice as large as A. Motion will again ensue by reason of their mutual attraction, and they will approach each other with a velocity continually increasing. In this instance, however, their speed will not be equal, the larger body, B, having a correspondingly less velocity than the smaller one, A. If, as we have supposed, it is twice as large, its velocity will be only one-half. But in this, as in the former case, the quantity of motion that each possesses is the same, for that depends on velocity and mass conjointly.

Fig. 91.

Further, if of the two bodies one becomes infinitely less as respects the other, then it is obvious that the little one alone will appear to move. This

condition is what actually obtains in the case of our earth, and bodies subjected to its influence. A mass of any kind, the support of which is suddenly removed, falls at once to the ground, and though in reality the earth moves to meet it just as much as it moves to meet the earth, the difference in these masses is so immeasurably great that the earth's motion is imperceptible, and may be wholly neglected.

The force by which bodies are thus solicited to move to the earth is called terrestrial gravity, or gravitation.

[Gravity is the reciprocal attraction of matter on matter; gravitation is the difference between gravity and the centrifugal force induced by the velocity of rotation or revolution.—*Somerville's* "*Connection of the Physical Sciences,*" *page* 437.]

The force of gravity depends on two different conditions: 1st, the mass; 2nd, the distance.

1st. The intensity of the force of gravity is directly as the mass. That is to say, that, for example, in the case of the earth, if its mass were twice as large, its force of attraction would be twice as great; or if it were only half as large, its attraction would only be half as much as it is.

2nd. In common with all other central forces, gravity diminishes as the distance increases. The law which determines this is expressed as follows:—"The force of gravity is inversely as the square of the distance;" that is to say, if a body be placed two, three, four, five times its original distance from another, the force attracting it will continually diminish, and in those different instances will successively be four, nine, sixteen, twenty-five times less than at first.

When a body, instead of being allowed to fall freely to the earth, is supported, its tendency to descend is not annihilated, but it exerts upon the supporting surface a degree of pressure. This pressure we speak of as WEIGHT. And inasmuch as the attractive force upon a body depends on its mass, it is obvious that if the mass is doubled, the weight is doubled; if the mass is tripled, the weight is tripled. Or, in other words, the weight of bodies is always proportional to their mass.

The absolute weight of a given body at the same place on the earth's surface is always the same; for the mass, and therefore the attractive force of the earth, never changes. If by any means the attractive influence of the earth could be doubled, the weight of every object would change, and be doubled correspondingly.

The absolute weight of bodies is determined by balances, springs, steelyards, and other such contrivances, as will be explained in their proper place. Different units of weight are adopted in different countries, and for different purposes, as the grain, ounce, pound, gramme, &c.

In bodies of the same nature the absolute weight is proportional to the volume. Thus a mass of iron which is twice the volume of another mass will also have twice its weight.

But when we examine dissimilar bodies the result is very different. A globe of water compared with one of copper, or lead, or wood of *the same size*, will have a very different weight. The lead will weigh more than the water, and the wood less.

This fact we have already pointed out by the term "*specific gravity*," or specific weight of bodies. And, inasmuch as it is obviously a relative thing, or a matter of comparison, it is necessary to select some substance which

shall serve to compare other bodies with; for solids and liquids, water is taken as the unit or standard of comparison. And we say that iron is about seven, lead eleven, quicksilver thirteen times as heavy as it; or that they have specific gravities expressed by those numbers. The unit of comparison for gaseous and vaporous bodies is atmospheric air.

When an unsupported body is allowed to fall, its path is in a vertical line. If a body be suspended by a thread, the thread represents the path in which that body would have moved. It occupies a vertical direction, or is perpendicular to the position which would be occupied by a surface of stagnant water. Such a thread is termed a plumb-line. It is of constant use in the arts to determine horizontal and vertical lines.

If in two positions, A B, Fig. 92, on the earth's surface, plumb-lines were suspended, it would be found that, though they are perpendicular as respects that surface, they are not parallel to one another, but incline, at a small angle, A C B, to each other. If their distance be one mile, this convergence would amount to one minute; and if it be sixty miles, the convergence will be one degree. Now, as the plumb-line indicates the path of a falling body, it is easily understood that on different parts of the earth's surface the paths of falling bodies have the inclinations just described. A little consideration shows that the descent of such bodies is in a line directed to the centre, C, of the earth.

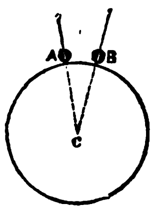


Fig. 92.

That centre we may therefore regard as the active point, or seat of the whole earth's attractive influence.

When examinations with plumb-lines are made in the neighbourhood of mountain masses, those masses exert a disturbing agency on the plummet, drawing the line from its true vertical position. But this is nothing more than what ought to place on the theory of universal gravitation; for that theory asserting that all masses exert an attractive influence, the results here pointed out must necessarily ensue, and the lateral action of the mountains correspondingly draw the plummet aside.

CHAPTER XIX.

THE DESCENT OF FALLING BODIES.

Accelerated Motion—Different bodies fall with equal Velocities—Laws of Descent as respects Velocities, Spaces, Times—Principle of Attwood's Machine—It verifies the laws of Descent—Resistance of the Atmosphere.

Observation proves that the force with which a falling body descends depends upon the distance through which it has passed. A given weight falling through a space of an inch or two may give rise to insignificant results: but if it has passed through many yards those results become correspondingly greater.

Gravity being a force continually in operation, a falling body must be under its influence during the whole period of its descent. The soliciting

action does not take effect at the first moment of motion and then cease, but it continues all the time, exerting, as it were, a cumulative effect. The falling body may be regarded as incessantly receiving a rapidly-recurring series of impulses, all tending to drive it in the same direction. The effect of each one is therefore added to those of all its predecessors, and a uniformly accelerated motion is the result.

Falling bodies are, therefore, said to descend with a uniformly accelerated motion.

As the attraction of the earth operates with equal intensity on all bodies, all bodies must fall with equal velocities. A superficial consideration might lead to the erroneous conclusion that a heavy body ought to descend more quickly than a lighter. But if we have two equal masses, apart from each other, falling freely to the ground, they will evidently make their descent in equal times or with the same velocity. Nor will it alter the case at all if we imagine them to be connected with each other by an inflexible line. That line can in no manner increase or diminish their time of descent.

The space through which a body falls in one second of time varies to a small extent in different latitudes. It is, however, usually estimated at sixteen feet and one-tenth.

As the effect of gravity is to produce a uniformly accelerated motion, the final velocities of a descending body will increase as the times increase; thus, at the end of two seconds, that velocity is twice as great as at one; at the end of three seconds three times as great; at the end of four, four times, and so on. Therefore the final velocity at the end

Of the first second is . . .	$32\frac{1}{5}$ feet.
,, second ,, . . .	$64\frac{2}{5}$,,
,, third ,, . . .	$96\frac{3}{5}$,,
&c., ,,	&c.

The spaces through which the body descends in equal successive portions of time increase as the numbers 1.3.5.7, &c.! that is to say, as the body descends through sixteen feet and one-tenth in the first second, the subsequent spaces will be

For the first second . . .	$16\frac{1}{10}$ feet.
,, second ,, . . .	$48\frac{3}{10}$,,
,, third ,, . . .	$80\frac{5}{10}$,,
&c.,	&c.

and these numbers are evidently as 1.3.5, &c.

The entire space through which a body falls increases as the squares of the times. Thus, the entire space is,

For the first second . . .	$16\frac{1}{10}$ feet.
,, second ,, . . .	$64\frac{2}{5}$,,
,, third ,, . . .	$144\frac{9}{10}$,,
&c.,	&c.

and these numbers are evidently as 1.4.9, &c., which are themselves the squares of the numbers 1.2.3, &c.

If a body continued falling with the final velocity it had acquired after falling a given time, and the operation of gravity were then suspended, it would descend in the same length of time through twice the space it fell through before relieved from the action of gravity.

The following Table embodies the results of the three first laws :—

Times	1.2.3.4.5.6.7, &c.
Final velocities	2.4.6.8.10.12.14, &c.
Space for each time . . .	1.3.5.7.9.11.13. &c.
Whole spaces	1.4.9.16.25.36.49, &c.

It would not be easy to confirm these results by experiments directly made on falling bodies, the space described in the first second being so great (more than sixteen feet), and the spaces increasing as the squares of the times. There is an instrument, however, known as Attwood's machine, in which the force of gravity being moderated without any change in its essential characters, we are enabled to verify the foregoing laws.

The principle of Attwood's machine is this. Over a pulley, A, Fig. 93, let there pass a fine silk line which suspends at its extremities equal weights, *b c*. These weights, being equally acted upon by gravity, will of course have no disposition to move; but now to one of the weights, *c*, let there be added another much smaller weight; these conjointly, preponderating over *b*, will descend, *b* at the same time rising. It might be supposed that the small additional weight, under these circumstances, would fall as fast as if it were unsupported in the air; but we must not forget that it has simultaneously to bring down with it the weight to which it is attached, and also to lift the opposite one. By its gravity, therefore, it does descend, but with a velocity which is less in proportion as the difference between the two weights to which it is affixed is less than their sum. It gives us a force precisely like gravity—indeed it is gravity itself—operating under such conditions as to allow a moderate velocity.

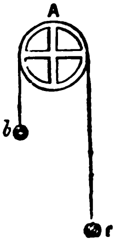


Fig. 93.

To avoid friction of the axle of the pulley, each of its ends rests upon two friction-wheels, as is shown at Q, Fig. 94; P is the pillar which supports the pulley. One of the weights is seen at *b*, the other moves in front of the divided scale, *c d*. This last weight is made to preponderate by means of a rod. There is a shelf which can be screwed opposite any of the divisions of the scale, and the arrival of the descending weight at that point is indicated by the sound arising from its striking. A clock, R, indicates the time which has elapsed. To enable us to fulfil the condition of suspending the action of gravity at any moment, a shelf, in the form of a ring, is screwed upon the scale at the point required. Through this the descending weight can freely pass, but the rod which caused the preponderance is intercepted. The equality of

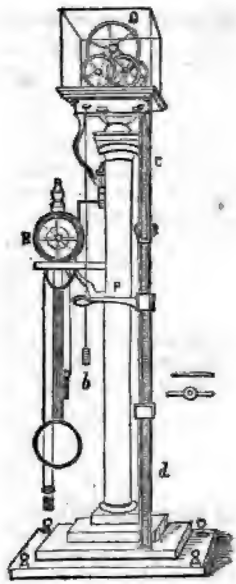


Fig. 94.

the two weights, is, therefore, reassumed, and the action of gravity virtually suspended.

By this machine it may be shown that, in order that the descending weight shall strike the ring at intervals of 1, 2, 3, 4, &c., seconds, counting from the time at which its fall commences, the ring must be placed at distances from the zero of the scale, which are as the numbers 1, 4, 9, 16, &c.; and these are the squares of the times. And in the same manner may the other laws of the falling of bodies be proved.

[Galileo himself made experiments regarding the free descent of bodies, which were subsequently repeated by Piccioli and Grimaldi from the tower of Degli Assinelli in Bologna. Dechalles has, however, made the most accurate observations on the subject. The spaces through which bodies fall are always smaller than we might be led to expect from theory. This difference depends, however, solely upon the resistance of the air, which increases in accordance with the square of the velocity. In the *falling-machine* of Attwood, and the falling-channel, the resistance of the air does not influence the results.—*Professor Müller on Physics and Meteorology, Lecture* 10.]

When a body is thrown vertically upward, it rises with an equably retarded motion, losing $32\frac{1}{6}$ feet of its original velocity every second. If in vacuo, it would occupy as much time in rising as in falling to acquire its original velocity, and the time expended in the ascent and descent would be the same.

Forces which, like gravity, in this instance produce a retardation of motion, are nevertheless designated as accelerating forces. Their action is such that, if it were brought to bear on a body at rest, it would give rise to an accelerated motion.

In rapid movements taking place in the astmosphere, a disturbing agency arises in the resistance of the air—a disturbance which becomes the more striking as the descending body is lighter, or exposes more surface. If a piece of gold and a feather are suffered to drop from a certain height, the gold reaches the ground much sooner than the feather. Thus, if in a tall air-pump receiver we allow, by turning the button, *a*, Fig. 95, a gold coin and a feather to drop, the feather occupies much longer than the coin in effecting its descent; and that this is due to the resistance of the air is proved by withdrawing the air from the receiver, and, when a good vacuum is obtained, making the coin and the feather fall again. It will now be found that they descend in the same time precisely, as shown in the above diagram.

Fig. 95.

Nor is it alone light bodies which are subject to this disturbance: it is common to all. Thus, it was found that a ball of lead, dropped from the dome of St. Paul's Cathedral, in London, occupied $4\frac{1}{2}$ seconds in reaching the pavement, the distance being 272 feet. But in that time it should have fallen 324 feet, the retardation being due to the resistance of the air.

It has been observed that the force of gravity is not the same on al parts of the earth. The distance fallen through in one second at the pole

is 16·12 feet; but at the equator it is 16·01 feet. This arises from the circumstance that the earth is not a perfect sphere, its polar diameter being shorter than its equatorial, and, therefore, bodies at the poles are nearer to its centre than at the equator. Thus, in Fig. 96, let N S represent the globe of the earth, N and S being the north and south poles, respectively. Owing to its polar being shorter than its equatorial diameter, bodies situated at different points on the surface may be at very different distances from the centre, and the force of gravity exerted upon them may be correspondingly very different.

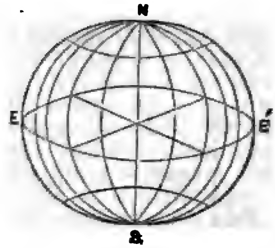


Fig. 96.

CHAPTER XX.

MOTION OF INCLINED PLANES.

Case of a Horizontal, a Vertical, and an Inclined Plane—Weight expended partly in producing pressure and partly motion—Law of Descent down Inclined Planes—Systems of Planes—Ascent up Planes—Parabolic theory of Projectiles—Disturbing agency of the Atmosphere—Resistance to Cannon Shot—Ricochet—Ballistic Pendulum.

WHEN a spherical body is placed on a plane set horizontally, its whole gravitation is expended in producing a pressure on that plane. If the plane is set in a vertical position the body no longer presses upon it, but descends vertically and unresisted. At all intermediate positions which may be given to the plane, the absolute attraction will be partly expended in producing a pressure upon that plane, and partly in producing an accelerated descent. The quantities of force thus relatively expended in producing the pressure and the motion will vary with the inclination of the plane: that portion producing pressure increasing as the plane becomes more horizontal, and that producing motion increasing as the plane becomes more vertical.

Let there be a ball descending on the surface of an inclined plane, A B, Fig. 97, and let the line, $d\ e$, represent its weight or absolute gravity. By the parallelogram of forces we may decompose this into two other forces, $d\ f$, and $d\ g$, one of which is perpendicular to the plane, and the other parallel to it. The first, therefore, is expended in producing pressure upon the plane, and the second in producing motion down it.

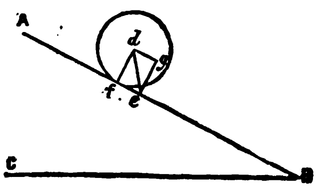


Fig. 97.

The following are the laws of the descent of bodies down inclined planes:

The pressure on the inclined plane is to the weight of the body as the base, B C, of the inclined plane, is to its length, A B.

The accelerated motion of a descending body is to that which it would have had if it fell freely, as the height, A C, of the plane is to its length, A B.

The final velocity which the descending body acquires is equal to that which it would have had if it had fallen freely through a distance equal to the height of the plane; and, therefore, the velocities acquired on planes of equal heights, but unequal inclinations, are equal.

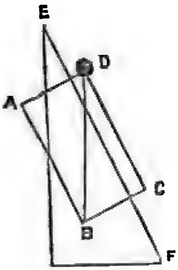


Fig. 98.

[It matters little what may be the inclination of the plane along which a body moves; the force must be calculated in the same manner; *i. e.*, by the parallelogram of forces. For example, suppose that the plane was very oblique, as E F, in Fig. 98, then we should say that the line, D C, was almost equal to the line D B; and hence that the force of the ball, D, moving on the inclined plane, E F, would differ very little from the force of the same body falling through air, and unobstructed otherwise than by the resistance of the atmosphere.

The space passed through by a body falling freely is to that gone over an inclined plane, in equal times, as the length of the plane is to its height.

[Galileo made several experiments with the inclined plane for the purpose of determining if the laws of falling bodies were correct. It is easy to see for ourselves, and therefore we will try an experiment with Galileo's inclined plane. Here is a narrow channel of wood, *a b*, which is made for the purpose of trying this experiment, having its inside made perfectly smooth; it is twelve feet long, and divided into feet and inches on the inside, and marked so that any person can readily distinguish the figures. Let us place one end, *b*, upon some stones, *c d*, so as to raise it above the other end, *a*. We will now place a ball in the channel, at the upper part, *b*, and you will see that when it is liberated, it will roll rapidly down the channel, and also that the spaces traversed in 1, 2, 3, and its seconds, are as the squares of the time necessary to traverse the spaces. By this experiment we learn what are the true laws of gravitation, and discover that gravity is an uniform accelerating force.]

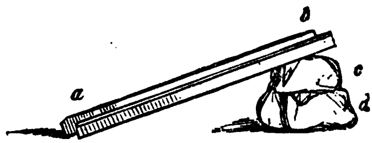


Fig. 99.

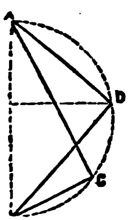


Fig. 100.

If a series of inclined planes be represented, in position and length, by the chords of a circle terminating at the extremity of the vertical diameter, the times of descent down each will be equal, and also equal to the time of descent through that vertical diameter. Thus, let A D, A G, D B, G B, be chords of a circle terminating at the extremities, A B, of the vertical diameter, and regarding these as inclined planes, a body will descend from A to D, or A to G, or D to B, or G to B in the same time that it would fall from A to B.

If a body descend down a system of several planes, A C, Fig. 101, with different inclinations, it would acquire the same velocity as it would have had in descending through the same vertical height, A B, though the times of descent are unequal.

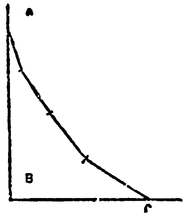


Fig. 101.

If a body which has descended an inclined plane meets at the foot of it a second plane of equal altitude, it will ascend this plane with the velocity acquired in coming down the first, until it has reached the same altitude from which it descended. Its velocity being now expended, it will re-descend, and ascend the first plane as before, oscillating down one plane, up the other, and then back again. The same thing will take place if, instead of being over an inclined plane, the motion be made over a curve, as in Fig. 102. In practice, however, the resistance of the air and friction soon bring these motions to an end.

Fig. 102.

In the motions of projectiles two forces are involved—the continuous action of gravity, and the momentary force which gave rise to the impulse—such as muscular exertion, the explosion of gunpowder, the action of a spring, &c.

The resulting effects of the combination of these forces will differ with the circumstances under which they act. If a body be projected downward in a vertical line, it follows its ordinary course of descent, its accelerated motion arising from gravity being conjoined to the original projectile force.

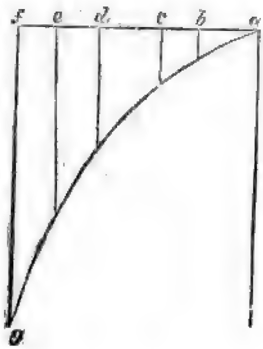


Fig. 103.

But if it be thrown vertically upward, the action of gravity is to produce an uniform retardation. Its velocity becomes less and less, until finally it wholly ceases. The body then descends by the action of the earth, the time of its descent being equal to that of its ascent, its final velocity being equal to its initial velocity.

[If a body be thrown in any other than a vertical direction, it will describe a curved line, the form of which may be easily deduced from the laws of falling. Let us assume the simplest case: for instance, that the body be urged by any force in a horizontal direction. If there were no such force as gravity, the body would continually move in a horizontal direction, and with an uniform velocity. By reason of the first impelling force, it would traverse the space, *a b*, in one second, the equally large space, *b c*, in two seconds, and so on, and must, consequently, at the end of the first, second, third, &c., seconds, have reached the points, *b c d*, &c. But it has sunk from the force of gravity: in the first second it fell 15 feet; consequently, at the end of that time, instead of being at *b*, it will be 15 feet below it. At the end of the next second, it is 60 feet below *c*; at the end of the third, 135 feet below it, &c. The curved line, *a g*, described by the body in this manner, is a parabola.—*Professor Müller's Lectures*, *Lecture* X.]

But if the projectile force forms any angle with the direction of gravity, the path of the body is in a parabolic curve, as seen in Fig. 104. If the direction of the projection be horizontal, the path described will be half a parabola.

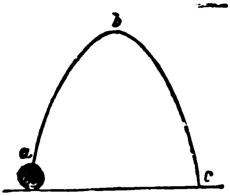


Fig. 104.

This, which passes under the title of the parabolic theory of projectiles, is found to be entirely departed from in practice. The curve described by shot thrown from guns is not a parabola, but another curve, the Ballistic. In vertical projections, instead of the times of ascent and descent being equal, the former is less. The final velocity is not the same as the initial, but less. Nor is the descending motion uniformly accelerated; but, after a certain point, it is constant. Analogous differences are discovered in angular projections.

The distance through which a projectile could go upon the parabolic theory, with an initial velocity of 2,000 feet per second, is about 24 miles; whereas no projectile has ever been thrown further than 5 miles.

In reality, the parabolic theory of projectiles holds only for a vacuum; and the atmospheric air, exerting its resisting agency, totally changes all the phenomena—not only changing the path, but, whatever may have been the initial velocity, bringing it speedily down below 1,280 feet per second.

The cause of this phenomenon may be understood from Fig. 105. Let B be a cannon-ball, moving from A to C with a velocity of more than 2,000 feet per second. In its flight it removes a column of air between A and B, and as the air flows into a vacuum only at the rate of 1,280 feet per second, the ball leaves a vacuum behind it. In the same manner it powerfully compresses the air in front. This, therefore, steadily presses it into the vacuum behind, or, in other words, retards it, and soon brings its velocity down to such a point that the ball moves no faster than the air moves— that is, 1,280 feet per second.

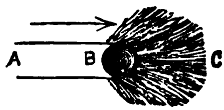


Fig. 105.

A shot, thrown with a high initial velocity, not only deviates from the parabolic path, but also to the right and left of it, perhaps several times. A ball striking on the earth or water at a small angle bounds forward or *ricochets*, doing this again and again until its motion ceases.

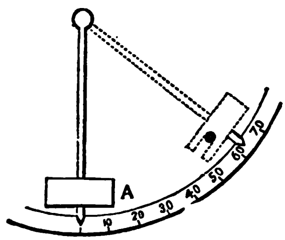


Fig. 106.

The initial velocity given by gunpowder to a ball, and, therefore, the explosive force of that material, may be determined by the Ballistic pendulum. This consists of a heavy mass, A, Fig. 106, suspended as a pendulum, so as to move over a graduated arc. Into this, at the centre of percussion, the ball is fired. The pendulum moves to a corresponding extent over the graduated arc, with a velocity which is less according as the weight of the ball and pendulum is greater than the weight of the ball alone.

The explosive force of gunpowder is equal to 2,000 atmospheres. It expands with a velocity of 5,000 feet per second, and can communicate to a ball a velocity of 2,000 feet per second. The velocity is greater with long than short guns, because the influence of the powder on the ball is longer continued.

CHAPTER XXI.

OF MOTION ROUND A CENTRE.

Peculiarity of Motion on a Curve—Centrifugal Force—Conditions of Free Curvilinear Motion—Motion of the Planets—Motion in a Circle—Motion in an Ellipse—Rotation on an Axis—Figure of Revolution—Stability of the Axis of Rotation.

In considering the motion of bodies down inclined planes, we have shown that the action of gravity upon them may be divided into two portions—one producing pressure upon the plane, and therefore acting perpendicularly to its surface ; the other acting parallel to the plane, and therefore producing motion down it.

It has also been shown that, in some respects, there is an analogy between movements over inclined planes and over curved lines, but a further consideration proves that between the two there is also a very important difference. A pressure occurs in the case of a body moving on a curve, which is not found in the case of one moving on a plane. It arises from the inertia of a moving body. Thus, if a body commences to move down an inclined plane, the force producing the motion is, as we have seen, parallel to the plane. From the first moment of motion to the last, the direction is the same, and inasmuch as the inertia of the body, when in motion, tends to continue that motion in the same straight line, no deflecting agency is encountered.

But it is very different with motion on a curve. Here the direction of descent from A to B is perpetually changing ; the curve from its form resists, and therefore deflects the falling body. At any point its inertia tends to continue its motion in a straight line ; thus, at A, were it not for the curve, it would move in the line A *a*, at B in the line B *b*, these lines being tangent to the curve at the points A and B. The curve, therefore, continually deflecting the falling body, experiences a pressure itself—a pressure which obviously does not occur in the case of an inclined plane. This pressure is denominated "centrifugal force," because the moving body tends to fly from the centre of the curve.

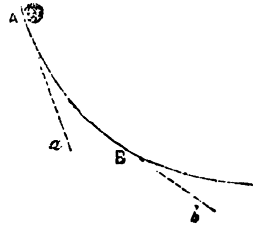


Fig. 107.

In the foregoing explanation we have regarded the body as being

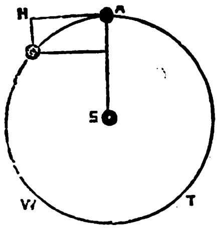


Fig. 108.

compelled to move in a curvilinear path, by means of an inflexible and resisting surface. But it may easily be shown that the same kind of motion will ensue without any such compelling or resisting surface, provided the body be under the control of two forces, one of which continually tends to draw it to the centre of the curve in which it moves, while the other, as a momentary impulse, tends to carry it in a different direction.

Thus, let there be a body, A, Fig. 108, attached by another body, S, and also subjected to a projectile force tending to carry it in the direction A H. Under the conjoined influence of the two forces it will describe a curvilinear orbit, A T W.

The point to which the first force solicits the body to move is termed the centre of gravity—that force itself is designated the centripetal force, and the momentary force passes under the name of tangential force.

The following experiment clearly shows how, under the action of such forces, curvilinear motion arises. Let there be placed upon a table a ball, A, and from the top of the room, by a long thread, let there be suspended a second ball, B, the point of suspension being vertically over A. If now we remove B a short distance from A, and let it go, it falls at once on A, as though it were attracted. It may be regarded, therefore, as under the influence of a centripetal force emanating from A. But if, instead of simply letting B drop upon A, we give it an impulse in a direction at right angles to the line in which it would have fallen, it at once pursues a curvilinear path, and may be made to describe a circle or an ellipse, according to the relative intensity of the tangential force given it.

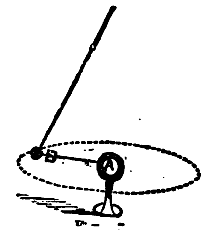


Fig. 109.

This revolving ball imitates the motion of the planetary bodies round the sun.

To understand how these curvilinear motions arise, let C be the centre of gravity, and suppose a body at the point *a*. Let a tangential force act on it in such a manner as to drive it from *a* to *b* in the same time as it would have fallen from *a* to *d*. By the parallelogram of forces it will move to *f*. When at this point, *f*, its inertia would tend to carry it in the direction *f g*, a distance equal to *a f*, in a time equal to that occupied in passing from *a* to *f*; but the constant attractive force still operating tends to bring it to *h*; by the parellologram of forces it therefore is carried to *k*; and by similar reasoning we might show that it will next be found at *n*, and so on. But when we consider that the centripetal force acts continually, and not by small interrupted impulses, it is obvious that, instead of a crooked line, the path which the body pursues will be a continuous curve.

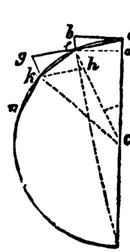


Fig. 110.

The planets move in their orbits round the sun, and the satellites round

their planets, in consequence of the action of two forces—a centripetal force, which is gravitation, and a tangential force originally impressed on them.

The centrifugal force obviously arises from the action of the tangential. It is the antagonist of the centripetal force.

The figure of the curve in which a body revolves is determined by the relative intensities of the centripetal and tangential forces. If the two be equal at all points, the curve will be a circle, and the velocity of the body will be uniform. But if the centrifugal force at different points of the body's orbit be inversely as the square of its distance from the centre of gravity, the curve will be an ellipse, and the velocity of the body variable.

In elliptical motion, which is the motion of planetary bodies, the centre of gravity is in one of the *foci* of the ellipse. All lines drawn from this point to the circumference are called *radii vectores*, and the nature of the motion is necessarily such that the *radius vector*, connecting the revolving body with the centre of gravity, sweeps over equal areas in equal times.

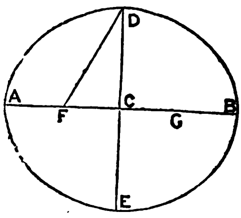


Fig. 111.

The squares of the velocities are inversely as the distances, and the squares of the times of revolution are to each other as the cubes of the distances. Let A B C D E, Fig. 111, be an elliptical orbit, as, for example, that of a planet, the longest diameter being A B, and the shortest D E. The points, F and G, are the *foci* of the ellipse, and in one, as F, is placed the centre of gravity, which, in this instance, is the sun. The planet, therefore, when pursuing its orbit, is much nearer to the sun when at A than when at B. The former point is, therefore, called the *perihelion*, the latter the *aphelion*, and D and E points of *mean distance*. The line A B, joining the perihelion and aphelion, is the *line of the apsides;* it is also the greater or *transverse axis* of the orbit, and D E is the *conjugate*, or less axis. A line drawn from the centre of gravity to the points D or E, as F D, is the *mean distance*, F is the *lower focus*, G the *higher focus*, A the *lower apsis*, B the *higher apsis*, and F C or G C—that is, the distance of either of the foci from the centre—the *eccentricity*.

When a body rotates upon an axis, all its parts revolve in equal times. The velocity of each particle increases with its perpendicular distance from the axis, and therefore so also does its centrifugal force. As long as this force is less than the cohesion of the particles, the rotating body can preserve itself; but as soon as the centrifugal force overcomes the cohesive, the parts of the rotating mass fly off in directions which are tangents to their circular motion.

There are many familiar instances which are examples of these principles; the bursting of rapidly rotating masses, the expulsion of water from a mop, the projection of a stone from a sling.

If the parts of a rotating body have freedom of motion among themselves, a change in the figure of that body may ensue by reason of the difference of centrifugal force of the different parts. Thus, in the case of the earth, the figure is not a perfect sphere, but a spheroid; the diameter or axis upon which it revolves, called its polar diameter, is less than its equatorial, it having assumed a flattened shape toward the poles, and a bulging one toward

the equator. At the equator, the centrifugal force of a particle is $\frac{1}{289}$ of its gravity. This diminishes as we approach the poles, where it becomes 0. The tendency to fly from the axis of motion has, therefore, given rise to the force in question.

This may be illustrated by an instrument represented in Fig. 112, which consists of a set of circular hoops, made of brass or other elastic material. They are fastened upon an axis at the point *a*, but at the point *b* can slide up and down the axis. When at rest they are of a circular form. By a multiplying wheel a rapid rotation can be given them, and when this is done they depart from the circular shape and assume an elliptical one, the shorter axis being the axis of rotation.

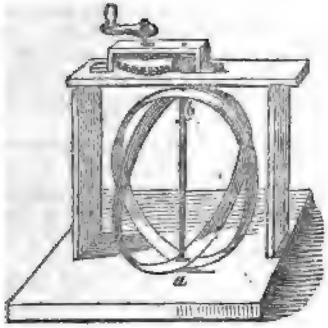


Fig. 112.

But if the parts of the rotating body have not perfect freedom of motion among themselves, their centrifugal force gives rise to a pressure upon the axis. If the mass is symmetrical as respects the axis, the resulting pressures compensate each other. But as each one of the rotating particles, by reason of its inertia, has a disposition to continue its motion in the same plane, it is obvious that such a *free axis* can only be disturbed from its position by the exercise of a force sufficient to overcome that effect. It is this result which is so well illustrated by Bohnenberger's machine, already described.

CHAPTER XXII.

OF ADHESION AND CAPILLARY ATTRACTION.

Adhesion of Solids and Liquids—Law of Wetting—Capillary Attraction—Elevations and Depressions—Relations of the Diameter of Tubes—Motions by Capillary Attraction—Endosmosis of Liquids and of Gases.

To the arm of a balance, *b c*, Fig 113, let there be attached a flat circular plate of glass, *a*, and let it be equipoised by the weights in the opposite scale, *d;* beneath it let there be brought a cup of water, *e*, and on lowering the glass plate within an inch, or even within the hundredth part of an inch of the water, no attraction is exhibited; but if the glass and the water are brought in contact, then it will require the addition of many weights in the opposite scale to pull them apart.

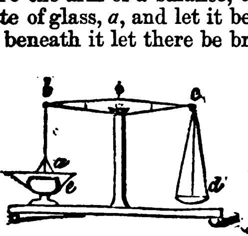


Fig. 113.

If the cup, instead of being filled with water, is filled with quicksilver, alcohol, oil, or any other liquid, or if instead of a plate of glass we use one of wood or metal, the same

effects still ensue. The force which thus maintains the surface in contact is called "Adhesion."

[If we cut a piece of lead into two parts with a clean knife, and afterwards press the newly-divided surfaces together, giving them a twisting motion at the same time, we shall find them adhere firmly. When india-rubber is cut with a clean knife, the fresh-cut surfaces will cohere in a similar manner.]

Adhesion does not alone take place between bodies of different forms. Two perfectly flat plates of glass or marble, when pressed together, can only be separated by the exertion of considerable force. In both this and the former case the absolute force required to effect a separation depends on the superficial area of the bodies in contact.

If, on bringing a given solid in contact with a liquid, the force of adhesion is equal to more than half the cohesive force of the liquid particles for one another, the liquid will adhere to the solid, or *wet* it. Thus, the adhesive force developed when gold is brought in contact with quicksilver is more than half the cohesion of the particles of the quicksilver for each other: the quicksilver, therefore, adheres to or wets the gold.

But if the force of adhesion developed between a solid and liquid is less than half the cohesive force of the particles of the latter, the liquid does not wet the solid. Thus, a piece of glass in contact with quicksilver is not wetted.

It is on these principles that Vera's pump acts. It consists of a cord which passes over two wheels, to which a rapid motion can be given. The water adheres to the cord, and is raised by it. See Fig. 73, Chap. XIII.

If the surface of some water be dusted over with lycopodium seeds, the fingers may be plunged in it without being wetted, the lycopodium preventing any adhesion of the water.

But it is in the phenomena of capillary attraction that we see the effects of adhesion in the most striking manner. These phenomena are exhibited by tubes of small diameter, called capillary tubes, because their bore is as fine as a hair. If such a tube, *a*, Fig. 114, be immersed in water, the water at once rises in it to a height considerably above its level in the glass cup, *b*.

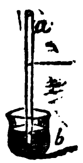


Fig. 114.

Or if instead of water we fill the glass cup with quicksilver, and immerse the tube in it, bringing it near the side, so that we can see the metal in the interior of the tube through the glass, it will be found to be depressed beneath its proper level.

These experiments are still more conveniently made by means of tubes bent in the form of a syphon, as represented in Fig. 51, Chapter X. If one of these be partially filled with water, and then with quicksilver, the water will be seen to rise in the narrow tube above its level in the wide tube, and the quicksilver to be depressed.

[Perhaps the most common examples we can furnish of capillary attraction are the following, which we adduce without comment:—1. A lump of sugar placed upon a wet surface becomes very soon saturated throughout. 2. A sponge placed in a saucer of water soon absorbs all the fluid. 3. A piece of blotting-paper applied to some ink upon a sheet of paper. 4. The action of the wicks of candles and lamps, &c.]

When tubes of different diameters are used, the change in the level of the liquid is different. The narrower the tube, the higher water will rise, and the lower will quicksilver be depressed.

When tubes are very wide, or what comes to the same thing, when liquids are contained in bowls or basins, the surface is found not to be uniformly level; but near those points where it approaches the glass, in the case of water it curves upward, and in the case of quicksilver it curves downward, as seen in Fig. 115.

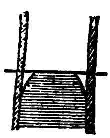


Fig. 115.

In tubes of the same material dipped in the same liquid, the elevations or depressions are inversely as the diameters of the tubes; the narrower the tube the higher will water rise, and the deeper will quicksilver be depressed.

There is a beautiful experiment which shows the connection between the diameter of the tube and the height to which it will lift a liquid. Two square pieces of plate glass, A B, C D, Fig. 116, are arranged so that their surfaces form a minute angle. This position may be easily given by fastening them together with a piece of wax or cork, K. When the plates are dipped into a trough of water, E F, G H, the water rises in the space between them to a smaller extent where the plates are far apart, and to a greater where they are closer. The upper edge of the water gives the form of a hyperbola, D I A. The plates may be supposed to represent a series of capillary tubes of diameters continually decreasing; they show that the narrower the intercluded space or bore of such tubes, the higher the liquid will rise.

The figure of the surface which bounds a liquid in a capillary tube is also to be remarked. Whenever a liquid rises in a tube, its bounding surface is concave upward, as seen in Fig. 117, where *f g* is the tube, and *a a* the surface. When the liquid neither rises nor sinks, the surface, *a a*, is plane,

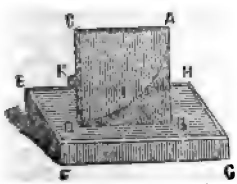


Fig. 116.

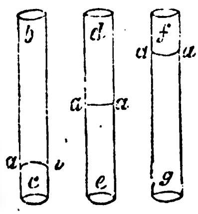


Fig. 117.

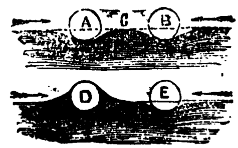


Fig. 118.

as at *d e*; when the liquid is depressed, the surface, *a a*, is convex upward, as seen at *b c*. All these conditions may be exhibited by a glass tube properly prepared. In such a tube, when quite clean, the concavity and elevation of the liquid are seen; if the interior of the tube be slightly greased, the surface of the water in it is plane, and it coincides in position with the level on the exterior. If it be not only greased, but also dusted with lycopodium, the liquid is depressed in it, and has a convex figure.

It may be shown, according to the principles of hydrostatics, that it is the assumption of this curved surface which is the cause of the elevation or depression of liquids in capillary tubes.

Motions often ensue among floating bodies in consequence of capillary attraction. At first sight they might seem to indicate the exertion of direct forces of attraction and repulsion emanating from the bodies themselves; but this in reality is not the case, the motions arising in consequence of a

disturbance of the figure of the surface on which the bodies float. Thus, if we grease two cork balls, A B, and dust them with lycopodium powder, they will, when set upon water, repel the liquid all round, each ball reposing in a hollow space. If brought near to each other, their repulsion exerted on the water at C makes a complete depression, and they fall toward one another as though they were attracting each other. It is, however, the lateral pressure of the water beyond which forces them together.

Again, if one of the balls, E, is greased and dusted with lycopodium, and the other, D, clean, and therefore capable of being moistened, an elevation will exist all round D, and a depression round E. When placed near together the balls appear to repel each other; the action in this case, as in the former, arising from the figure of the surface of the water.

If we take a small bladder, or any other membranous cavity, and having fastened it on a tube open at both ends, A B, Fig. 119, fill the bladder and tube to the height, C, with alcohol, and then immerse the bladder in a large vessel of water, it will soon be seen that the level at C is rising, and at a short time it reaches the top of the tube at B, and overflows. This motion is evidently due to the circumstance that the water percolates through the bladder, and the phenomenon has sometimes been called endosmosis, or inward movement. Examination proves that while the water is thus flowing to the interior, a little of the alcohol is moving in the opposite way; but as the water moves quicker than the alcohol, there is an accumulation in the interior of the bladder, and, consequently, a rise at C.

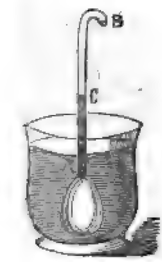


Fig. 119.

One liquid will thus intrude itself into another with very great force. A bladder filled full of alcohol, and its neck thickly tied, will soon burst open if it be plunged beneath water.

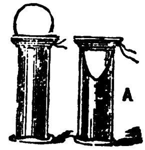


Fig. 120.

Similar phenomena are exhibited by gases. If a jar be filled with carbonic acid gas, and a piece of thin india-rubber tied over it, the carbonic acid escapes into the air through the india-rubber, which becomes deeply depressed, as at A, Fig. 120. But if the jar be filled with air, and be exposed to an atmosphere of carbonic acid, this gas, passing rapidly through it, accumulates in the interior of the vessel, and gives to the india-rubber a convex or dome-shaped form, as seen at B.

Endosmosis is nothing but a complex case of common capillary attraction. The facts here described were originally discovered by Priestley; but, at a later period, attention was called to them by Dutrochet, who, regarding them as being due to a peculiar physical principle, gave to the movements in question the names of endosmose and exosmose, meaning inward and outward motion. But I have shown that there is no reason to revert to any peculiar physical principle, since the laws of ordinary capillary attraction explain every one of the facts.

The bursting of a bladder, filled with alcohol and sunk under water, gives us some idea of the power with which the latter liquid forces its way into the membranous cavity; and it is surprising with what a degree of energy these movements are often accomplished. An opposing pressure of two or three atmospheres seems to offer no obstacle whatever, and I have seen gases

pass through india-rubber to mingle with each other, though resisted by pressures of from twenty to fifty atmospheres.

Whenever liquids which can commingle are placed on opposite sides of a membrane or cellular body which they can wet, motion ensues; both liquids simultaneously moving in opposite directions, and commonly one much faster than the other. Thus, if a bladder full of gum-water is immersed in common water, the latter will find its way into the former against any pressure whatever.

During the growth of trees, the terminations of their roots, which are of a soft and succulent nature, and which pass under the name of *spongioles*, are filled with a gummy material which originally was formed in the leaves. The moist or wet soil with which the *spongioles* are in contact continually furnishes a supply of water, which enters those organs in precisely the same way that it would enter a bladder full of gum-water. An accumulation takes place in the organs, and the liquid rises in the vascular parts of the root and the stem, which are in connection therewith. To this we give the name of *ascending sap*. It makes its way to the leaves, there to be changed into gum-water by the action of the light of the sun. It is immaterial how high a tree may be; the force now under consideration is competent to lift the sap to any altitude.

SECTION IV.—PROPERTIES OF SOLIDS.

CHAPTER XXIII.

GENERAL PROPERTIES OF SOLIDS.

Distinctive Properties — Changes by particular Processes — Absolute Strength —Lateral Strength —Resistance to Compression — Torsion — Torsion Balance.

A SUBSTANCE which can of itself maintain an independent figure has already been defined as a solid body. This peculiarity arises from the relative intensity of the attractive and repulsive forces which obtain among its particles. In solids the attractive predominates over the repulsive force; in liquids there seems to be little difference in their intensity; in gases the repulsive force prevails. It is further to be observed, that portions of gas uniformly mix with each other; the same also takes place with liquids of a similar kind; but when a fragment is broken from a solid mass mere coaptation will not effect reunion.

The cohesive force of solids is exhibited in very different degrees—some solids being brittle, and some ductile—some are hard, and others soft. Thus glass and bismuth may be pulverized in a mortar; but gold can be beaten out to an incredible extent by a hammer, and copper drawn into fine wires. The diamond is the hardest of all substances known, and, from their possessing the same quality, rhodium and iridium are used for the tips of metallic pens, while other solids, such as potassium, sodium, butter, are soft, and yield to a very moderate pressure.

It has already been stated that the special properties which bodies possess can often be changed by proper processes. Thus glass, by slow cooling, loses much of its brittleness; and steel may be made excessively hard by being ignited, and then plunged in cold water. Prince Rupert's drops

furnish an illustration of these effects; they are made by suffering drops of melted glass to fall in water. The drop takes on a pear-shaped form, terminating in a long thread. It will stand a tolerably heavy blow on the thick part, but bursts to dust if the tip of the thin part is broken.

Solid substances differ very much in the important peculiarity of STRENGTH. Of all bodies steel is the strongest. The strength of materials may be considered in four ways:—

1st. Absolute strength, or the resistance exerted against a force tending to tear asunder.

2nd. Lateral or respective strength—the resistance exerted against being brcken across.

3rd. Resistance to compression—that is, to a force tending to crush.

4th. Strength of torsion—the resistance against separation by being twisted.

The absolute strength of a body may be determined by fastening its upper end, and attaching weights to the lower till it breaks. The absolute strength is not affected by the length of a body, but is proportional to the area of its section. A rod of tempered steel, the area of which is one inch, requires nearly 115,000lbs. to tear it asunder. The strength of cords depends on the fineness of the strands; damp cordage is stronger than dry. Silk cords, of the same diameter, have thrice the strength of those of flax, and a remarkable increase of power arises from gluing the threads together. A hempen cord, the threads of which are glued, is stronger than the best wrought iron.

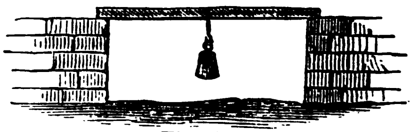


Fig. 121.

The lateral strength of a beam of the shape of a parallelopipedon and of uniform thickness, supported at its ends and loaded in the middle, is inversely as the length and directly as the product of the breadth into a square of the depth, as in Fig. 121. This strength is least when the whole weight acts in the middle, and is greatest when at the ends.

The resistance to compression increases as the section of the body increases, and it diminishes as the body becomes longer. When the body is only a thin plate, its resistance to compression is, however, very small; but it rapidly increases with increasing thickness, reaches a maximum, and then diminishes as the square of the length. This species of resistance is called into operation in the construction of pillars or columns.

[The resistance of bodies to forces tending to crush them is given by Mr. Hodgkinson ("Philos. Trans.," 1840), in the following table:—

Description of Wood.	Strength per Sq. In. in lbs.			Description of Wood.	Strength per Sq. In. in lbs.		
Alder	6,831	to	6,960	Mahogany	8,198	to	——
Ash	8,683	,,	9,363	Oak (Quebec)	4,231	,,	5,982
Bay	7,518	,,	——	,, (English)	6,484	,,	10,058
Beech	7,733	,,	9,363	Pine (pitch)	6,790	,,	——
English Birch	3,297	,,	6,402	,, (red)	5,395	,,	7,518
Cedar	5,674	,,	5,863	Poplar	3,107	,,	5,724
Red Deal	5,748	,,	6,586	Plum (dry)	8,241	,,	10,493
White Deal	6,781	,,	7,293	Teak	——	,,	12,101
Elder	7,451	,,	9,973	Walnut	6,063	,,	7,227
Elm	——	,,	10,331	Willow	2,898	,,	6,128
Fir (spruce)	6,499	,,	6,819				

[All the experiments were made upon short pillars of wood, and the force applied in the direction of the fibres. The results of the first column are deduced from experiments made upon cylinders one inch in diameter, moderately dry, and two inches long. The second column is formed from experiments made upon cylinders of the same size, kept in a warm place for two months; thus proving that wet timber is weaker than dry.]

Torsion resistance is connected with the elasticity of a body. As respects this force, elasticity, we have alrdady defined it, and shown that no solid substance is perfectly elastic, though gases are. Each solid has its own limit of elasticity, beyond which, if it be strained, it takes a permanent set, or it breaks. Mr. Tredgold found that a weight of 93,000lbs. upon a square inch of cast-iron crushed it, but that the same material will sustain a weight of 15,300lbs. without any alteration. The limit of elasticity of glass is the point at which it breaks, and that of iron or copper being reached, the metal takes a permanent set.

THE TORSION BALANCE consists of a delicate thread of glass, or other highly elastic substance, *a b*, Fig. 122, fastened at its upper end, *a*, to a button, which turns stiffly in the graduated plate, *c*; and to its lower end at *b*, a lever, *b d*, is affixed transversely. The thread is inclosed in a glass tube, B, and the transverse lever moves in a glass cylinder, A. It is thus protected from the disturbance of currents of air. Round this cylinder, from 0 to 180, graduated divisions are marked, and the whole instrument can be levelled by means of screws, *f f*.

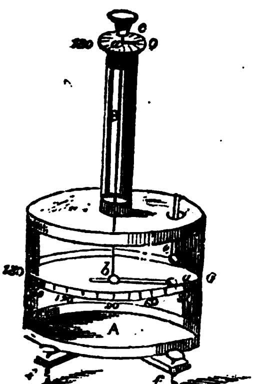


Fig. 122.

Suppose, now, it were required to measure any feeble repulsive force, as the repulsion of a little electrified ball, *e*. If this ball be introduced into the interior of the cylinder through an aperture in the top, as shown in Fig. 122, the index at *c* and the ball at *d* being both at the zero of their respective scales, the repulsion of *e* will drive the movable ball, *d*, through a certain number of degrees. By twisting the button at *a* we can compel *d* to go back to its original position; and the number of degrees through which the thread must be twisted to effect this measures the repulsive force, for the angle of torsion is always proportional to the force exerted. Of all the methods for determining feeble forces in a horizontal plane, the torsion balance is the most delicate and accurate.

CHAPTER XXIV.

THE CENTRE OF GRAVITY.

Definition of the Centre of Gravity — Line of Direction — Position of Equilibrium—Three Conditions of Support—Resulting States of Equilibrium—Stability of Bodies—The Floating of Bodies.

IN every solid body there exists a certain point round which its material particles are arranged so as to be equally acted on by gravity. The gravi-

tating forces soliciting these particles may be regarded as acting in lines which are parallel to one another; for the common point of attraction, the centre of the earth, is so distant, that lines drawn from it to the different particles of any body on its surface are practically parallel. To this point, thus found in every body, no matter what may be its figure or density, the term "*Centre of Gravity*" is applied.

[If an immovable straight line, *a b*, Fig. 123, be supported at its centre and loaded at both ends with equal weights, the whole will be in equilibrium, in whatever direction the line be turned round the point at which the central force acts, whether the line be in the position *a b*, or in the position *a' b'*. Let us assume that the two points, *a* and *b*, are two heavy molecules, connected by the straight rigid rod, *a b*, supposed devoid of weight, then it is clear that equilibrium must occur if only the point, *c*, be supported, whatever be the position of the line, *a b*. The point, *c*, would be nothing more than the centre of gravity of the body consisting of the two molecules. We may regard the actions of the forces of gravity of the two molecules combined at the centre of gravity, without on that account the equilibrium being disturbed.—*Professor Müller's "Physics and Meteorology," Lecture* III.]

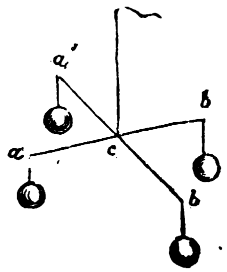


Fig. 123.

A line which connects the centre of gravity with the centre of the earth (or, what is the same thing, a line drawn from the centre of gravity perpendicularly downward), is called the "*line of direction.*" If a solid be suffered to fall, its centre of gravity moves along the line of direction until it reaches the ground.

In our reasonings in relation to solids, we may regard them as if all their material particles were concentrated in one point—that point being the centre of gravity—this being the point of application of the earth's attraction. It follows, therefore, that if a body have freedom of motion, it cannot be brought into a position of permanent equilibrium until the centre of gravity is at the lowest place.

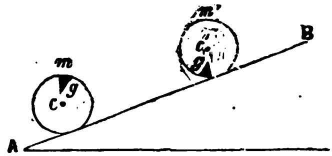


Fig. 124.

To satisfy this condition, sometimes effects which are apparently contradictory will ensue. Thus, the cylinder *m*, Fig. 124, so constructed, by being weighted on one side, as to have its centre of gravity at the point, *g*, while its geometrical centre is at *c*, will roll *up* an inclined plane, A B, continuing its motion until, as shown at *m'*, where the centre of gravity, *g'*, is in the lowest position.

A prop which supports the centre of gravity of a body supports the whole body. There are three different positions in which this support may be given:—

1st. The prop may be applied directly to the centre itself.

2nd. The point of support may have the centre immediately below it.

3rd. The point of support may have the centre immediately above it.

In the first case, when the point of support is directly applied to the centre

of gravity itself, the body, whatever its figure may be, will remain at rest in any position—as is the case in a common wheel, the centre of gravity of which is in the centre of its figure, and this being supported upon the axle, the wheel rests indifferently in any position.

Let *b a d*, Fig. 125, be a brass semicircle, weighted at the parts *b d* to such an extent that the centre of gravity falls upon the line connecting *b* and *d*. To *a* fasten a light arm, *a c*, long enough to reach to that line, and on this arm, as shown by the figure, the whole body may be balanced.

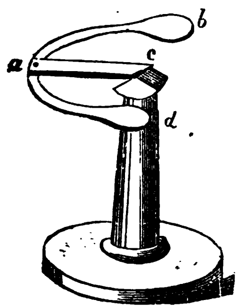


Fig. 125.

2nd. The point of support may be above the centre of gravity. In this case, if the body have freedom of motion, it will not rest in equilibrio until its centre of gravity has descended to the lowest position possible, or until it is perpendicularly beneath the point of suspension. Thus, let there be a circular plate, E c, Fig. 126, the centre of gravity of which is at *c*, and let it be suspended at the point, E, having freedom of motion on that point. Whatever position we may give it to the right or left, as shown by the dotted lines, it at once moves, and is only at rest when E and *c* are in the same perpendicular line.

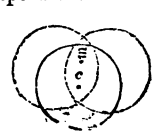


Fig. 126.

In the same manner, if a ball be suspended to a point by a thread, whatever position may be given it, there is but one in which it will remain at rest, and that is when its centre of gravity is immediately beneath the point of suspension, and the thread in a vertical line.

3rd. The point of support may be beneath the centre of gravity. In this case, also, the body will be in equilibrio and at rest; but the nature of its equilibrium differs essentially from that of the foregoing case, as we shall presently see. A sphere upon a horizontal plane affords a case in point; and, as its centre of gravity is also its centre of figure, it will be at rest, no matter what may be the particular point of its surface to which the support is applied.

Upon the principle that if a body be suspended freely, and a perpendicular be drawn from the point of suspension, it will pass through the centre of gravity, we are often enabled to determine the position of that centre experimentally. Thus, let the plane body, A B C, Fig. 127, be supported by a thread attached to the point, A, and to the same point let there be attached a plumb-line; this line, because it is perpendicular, will pass through the centre of gravity; let the line A *m*, against which the plumb-line hangs, be marked upon the body; next let it be suspended in like manner by another point, B, to which the plumb-line is also attached; the direction, B *m'*, of the plumb-line will, in this case, intersect its direction in the former case at some point, such as G. This will be the centre of gravity.

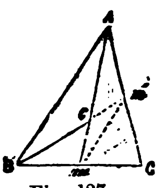


Fig. 127.

[To find the centre of gravity of a polygon, the figure must be divided

into triangles, as shown in Fig. 128, and then the centre of gravity of each triangle must be found. As soon as this is done, you have only to find the resultant of the forces acting upon the centres of gravity of the triangles; and this will give the centre of gravity of the whole.

[If it is required to find the centre of gravity of a triangular pyramid, it will be necessary to draw lines from the angle, a and b, Fig. 129, towards the centres of gravity, e and e', of the opposite triangles. Where these two lines cut each other at e'' is the centre of gravity.

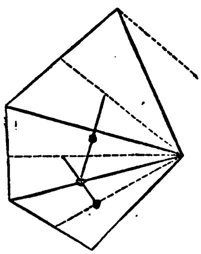


Fig. 128.

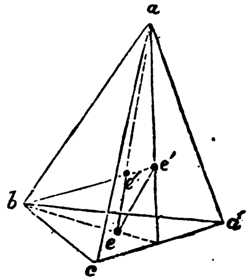


Fig. 129.

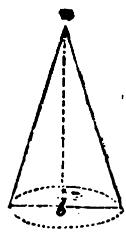


Fig. 130.

[The centre of gravity of a cone, Fig. 130, with a circular base, lies on the straight line which passes from the apex, a, to the centre of the base, b, and its distance from the central point, b, of the base is $\frac{1}{4}$ of the whole line.

[The centre of gravity of a straight line is *exactly* in the middle.]

When the centre of gravity is above the point of suspension, there is produced a pressure upon that point. When the centre of gravity is beneath the point of suspension, there is produced a pull upon that point.

The stability of bodies is intimately connected with the position of their centre of gravity. A body may be in a condition, 1st, of indifferent; 2nd, of stable; 3rd, of instable equilibrium.

Indifferent equilibrium ensues when a body is supported upon its centre of gravity; for then it is immaterial what position is given to it—it remains in all at rest.

Stable equilibrium ensues when the point of support is above the centre of gravity. If the body be disturbed from this situation, it oscillates for a time, and finally returns to its original position.

Instable equilibrium is exhibited when the point of support is beneath the centre of gravity. The body being movable, in this instance it revolves upon its point of support, and turns into such a position that its centre of gravity comes immediately beneath that point.

In the theory of the balance, hereafter to be described, these facts are of the greatest importance.

When bodies are supported upon a basis, their stability depends on the position of their line of direction. The line of direction has already been defined to be a line drawn from the centre of gravity perpendicularly downward.

If the line of direction falls within the basis of support, the body remains supported.

If the line of direction falls outside the basis of support, the body overturns.

Thus, let there be a block of wood or metal, Fig. 131, of which *c* is the centre of gravity, *c d* the line of direction, and let it be supported on its lower face, *a b*; so long as the line of direction falls within this basis, the block remains in equilibrio.

Again, let there be another block, Fig. 132, of which *c* is the centre of gravity, and *c d* the line of direction. Inasmuch as this falls outside of the basis, *a b*, the body overturns.

A ball upon a horizontal plane has its line of direction within its point of support; it therefore rests indifferently in any position in which it may be laid. But a ball upon an inclined plane has its line of direction outside its point of support, and therefore it falls continually.

From similar considerations we understand the nature of the difficulty of poising a needle upon its point. The centre of gravity is above the point of support, and it is almost impossible to adjust things so that the line of direction will fall within the basis. The slightest inclination instantly causes it to overturn.

When the centre of gravity is very low, or near the basis, there is more difficulty in throwing the line of direction outside the basis than when it is

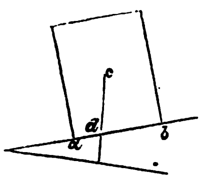


Fig. 131.

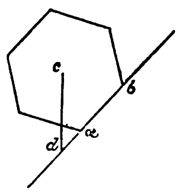


Fig. 132.

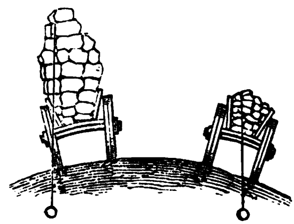


Fig. 133.

high. For this reason carriages which are loaded very high, or have much weight on the top, are more easily overturned than those the load of which is low, and the weight arranged beneath, as is shown in Fig. 133.

The stability of a body is greater according as its weight is greater, its centre of gravity lower, and its basis wider.

The principles here laid down apply to the case of the flotation of bodies. When an irregular-shaped solid mass is placed on the surface of a fluid, it arranges itself in a certain position, to which it will always return if it be purposely overset. In many such solids another position may be found, in which they will float in the liquid; but the slightest touch overturns them. Bodies, therefore, may exhibit either *stable* or *unstable* flotation. A long cylinder floating on one end is an instance of the latter case, but if floating with its axis parallel to the surface of the liquid, of the former.

These phenomena depend on the relative positions of the centre of gravity of the floating solid, and that of the portion of liquid which it displaces. The

former retains an invariable position as respects the solid mass, but the latter shifts in the liquid as the solid changes its place.

Equilibrium takes place when the centre of gravity of the floating body and that of the portion of liquid displaced are in the same line of direction. If of the two the former is *undermost*, stable equilibrium ensues; but if it is *above* the centre of gravity of the displaced liquid, unstable equilibrium takes place. To this, however, there is an exception—it arises when a body floats on its largest surface.

There are two forces involved in the determination of the position of flotation: 1st, the gravity of the body downward; 2nd, the upward pressure of the liquid. The former is to be referred to the centre of gravity of the body itself, and the latter takes effect on the centre of gravity of the displaced liquid. If these two centres are in the same vertical line, they counteract each other; but in any other position a movement of rotation must ensue. The solid, therefore, turns over, and finally comes into such a position as satisfies the conditions of equilibrium.

On these principles a cube will float on any one of its faces, and a sphere in any position whatever; but if the sphere be not of uniform density, one part of it being heavier than the rest, motion takes place until the heaviest part is lowest. A long cylinder floating on its end is unstable, but when it floats lengthwise, stable. It is obvious that these principles are of great importance in ship-building, and the loading and ballasting of ships.

CHAPTER XXV.

THE PENDULUM.

Simple and Physical Pendulums—Nature of Oscillatory Motion—Centre of Oscillation—Laws of Pendulums—Cycloidal Vibrations—The Seconds' Pendulum—Measures of Time, Space, and Gravity—Compensation Pendulums.

A SOLID body suspended upon a point with its centre of gravity below, so that it can oscillate under the influence of gravity, is called a pendulum.

A simple pendulum is imagined to consist of an imponderable line, having freedom of motion at one end, and at the other a point possessing weight.

A physical pendulum consists of a heavy metallic ball, suspended by a thread or slender wire.

The position of rest of a pendulum is when its centre of gravity is perpendicularly beneath its point of suspension; its length, therefore, is in the line of direction. If it be removed from this position, it returns to it again after making several oscillations backward and forward. Its descending motions are due to the gravitating action of the earth, its ascending due to its own inertia. A pendulum once in motion would vibrate continually were it not for friction on its point of suspension, the rigidity of the thread, if it be supported by one, and the resistance of atmospheric air.

The length of a pendulum is the distance that intervenes between its point of suspension and its centre of oscillation. Its *oscillation* is the extreme distance through which it passes from the right hand to the left, or from the left to the right. In Fig. 134 *a* is the point of suspension; *b* the centre of oscillation; *a b* the length of the pendulum; *c b d* or *d b c*, the oscillation; the angle a' or β is the angle of elongation; and the time is the period that elapses in making one complete oscillation. Oscillations are said to be isochronous * when they are performed in equal times.

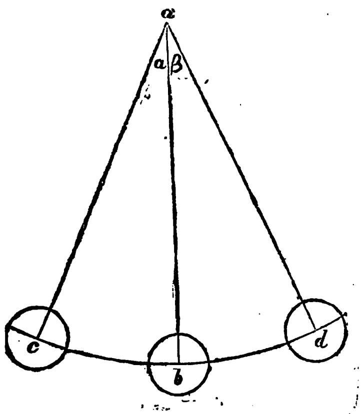


Fig. 134.

[The motion from *c* to *b* is a semi-descending oscillation, from *b* to *d* a semi-ascending oscillation. The *amplitude* of an oscillation is the magnitude of the arc, *a d*, expressed in degrees, minutes, and seconds. The *time* of an oscillation is the time necessary for the pendulum to traverse this arc.]

Fig. 135.

Let *a b c*, Fig. 135, be a pendulous body, supported on the point, *a*, and performing its oscillations upon that point. If we consider the motions of two points, such as *b* and *c*, it will appear that under the influence of gravity the point, *b*, which is nearer to the point of suspension, would perform its oscillations more quickly than the point, *c*. But inasmuch as in the pendulous body both are supposed to be inflexibly connected together, by reason of the solidity of the mass, both are compelled to perform their oscillations in the same time. The point, *b*, will, therefore, tend to accelerate the motions of *c*, and *c* will tend to retard the motions of *b*. It follows, therefore, that in every pendulum there is a point the velocity of which, multiplied by the mass of the pendulum, is equal to the quantity of motion in the pendulum. To this point the name of centre of oscillation is given. In a linear pendulum—that is, a rod of inappreciable thickness—the centre of oscillation is two-thirds the length from the point of suspension. In a right-angled conical mass the centre of oscillation is at the centre of the base.

The centre of oscillation possesses the remarkable property that it is convertible with the centre of suspension—that is to say, if a pendulum vibrates in a given time, when supported on its ordinary centre of suspension, it will vibrate in the same time exactly if it be suspended on its centre of oscillation. Advantage has been taken of this property to determine the lengths of pendulums with great precision, and thereby the intensity of gravity and the figure of the earth. In these cases a simple bar of metal, of proper length, with knife-edges equidistant fromi ts ends, has been used, and adjust-

* This word is derived from the Greek *isos*, equal, and *chronos*, time. The term signifies equality of time.

ment made until the bar vibrated equally when supported on either knife-edge. The distance between the knife-edges is the length of the pendulum.

Pendulums of equal lengths vibrate in the same place in equal times, provided their angles of elongation do not exceed two or three degrees.

Pendulums of unequal lengths vibrate in unequal times—the shorter more quickly than the longer—the times being to one another as the square roots of the lengths of the pendulums.

If we take a circle, B, Fig. 136, and, causing it to roll along a plane, B D, mark out the path which is described by a point, P, in its circumference, the line so marked is designated a cycloid.*

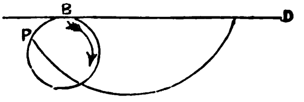


Fig. 136.

When a pendulum vibrates in a cycloid, it will describe all arcs thereof in equal times; and the time of each oscillation is to the time in which a heavy body would fall through half the length of the pendulum as the circumference of a circle is to its diameter.

The difference, therefore, between oscillation in cycloidal and circular arcs is, that in the former all oscillations are isochronous, but in the latter they are not; for the larger the circular are the longer, the time of oscillation. And as circular movement is the only one which can be conveniently resorted to in practice, it is necessary to reduce circular to cycloidal oscillations by calculation.

When the length of the pendulum is such that its time of oscillation is equal to one second, it is called a seconds' pendulum. This length differs at different places.

[The following table shows the length of the seconds' pendulum, in English inches, at several places where it has been tried. It is taken from Mr. Airey's treatise on the "Figure of the Earth," in the "Encyclop. Metrop."

Stations.	Latitude.	Length of Pendulum.	Observers.	Station.	Latitude	Length of Pendulum	Observers.
	° ′	Inches.			° ′	Inches.	
Spitzbergen ...	79 50 N	39·21469	Sabine.	Sandwich Islands .	20 52	39·04690	Freycinet.
Unst	60 45	39·17162	Biot & Kater	Trinidad	10 39	39·01888	Sabine.
Leith Fort ...	55 59	39·15546	Biot & Kater	St. Thomas	0 25	39·02074	Sabine.
London........	51 31	39·13929	Kater	Bahia	12 59 S	39·02433	Sabine.
Paris	48 50	39·12851	Borda, Biot, and Sabine's mean.	Isle of France......	20 10	39·04684	Freycinet and Duperry.
Bordeaux	44 50	39·11296	Biot	Cape of Good Hope	35 55	39·07800	Freycinet and Fallows.
New York ...	40 43	39·10120	Sabine.				
Formentera ...	38 40	39·09510	Biot (twice).				

Some allowance must be made for the error in the correction for the density of the air, about ·0018 for each.]

Under the equator it is shorter than at the poles; and this evidently arises from the circumstance that the intensity of gravity, as has been already explained, is different at those points; for the figure of the earth not being a perfect sphere, but an oblate spheroid, its polar axis being shorter than its equatorial, a body at the poles is more powerfully attracted than one at the

* This word is derived from the Greek *kuklos*, a circle, and *eidos*, like. The term signifies a curve generated by the rotation of a circle along a right line.

equator, it being nearer the centre of the earth; and as the motion of the pendulum arises from gravity, in order to make it oscillate in equal times, it is necessary to have it shorter at the equator than at the pole. The length of the seconds' pendulum in London is 39·13929 inches, at a temperature of 60° Fahrenheit.

For many of the purposes of physical science the pendulum is an important instrument. It affords us the best measure of time, and is, therefore, used in all stationary timepieces or clocks. [The manner in which the pendulum regulates a clock may be readily understood by examining the accompanying figure. It is well known that every clock must have an accelerating force to produce the motion and keep it going. This is supplied by the weight, *c*, which is attached to a line passing round the axis of a toothed wheel, *e*. Now, according to the law of falling bodies, the weight is drawn down by its gravity, and pulling down the line at the same time, it turns the axis, and causes the toothed wheel to revolve. If there was not anything to check the revolution of the wheel, its motion would become accelerated; but this is prevented by a beam, *a b*, with a tooth at each end, which catches the teeth of the wheel on either side, and as this beam is attached to the pendulum-rod, the motion of the wheel becomes regulated, because the wheel can only move one tooth's distance at each vibration of the pendulum. For example, when the ball of the pendulum, *d*, passes to the right of the weight, *c*, the end of the beam, *a*, which is now represented as being raised, will be depressed, and the other end, *b*, be raised instead. This contrivance is called an *escapement*. A clock is a mechanical apparatus for the purpose of registering the numbers of oscillations which a pendulum makes, and at the same time of communicating to the pendulum the amount of motion it is continually losing by friction on its points of support, and by resistance of the air. The oscillations are performed in small circular arcs, so that the times are equal.

Fig. 137.

Whatever affects the length of the pendulum changes the time of its motion. [The slightest variation in the length of the pendulum, that is, the distance of the weight from the point of suspension, influences the time of its oscillation; and this may be readily explained according to the law of the descent of bodies along inclined surfaces. For it is obvious that, since the ball of a short pendulum has to move down a much *steeper* curve than the ball of a long one, it must therefore descend much faster; so that a very slight diminution in the length of the pendulum, by increasing the steepness of the curve even in a very trifling degree, will diminish the line of its oscillations; and though this diminution may not be perceptible when two or three, or even twenty or thirty, are counted, it becomes very evident

when a large number are registered, as they are in a clock. In regulating a clock, therefore, we shorten the pendulum (by turning a screw at the bottom, which slightly raises the weight) when we desire it to go faster; and lengthen it by letting down the weight a little when we desire it to go slower. An alteration of no more than $\frac{3}{10}$ths of an inch will make a difference of five minutes a day in the going of a clock.—*Dr. Carpenter's "Mechanical Philosophy."*] It is for this reason that clocks go slower in summer and faster in winter—the changes of temperature altering the length of the pendulum. To compensate this, various contrivances have been resorted to with a view of securing the invariability of the instrument. The nature of these is very well illustrated by the mercurial pendulum, which was invented by Mr. George Graham, a watchmaker, who tested its action in 1721.

Let A B, Fig. 138, be the pendulum-rod; at B it is formed into a kind of rectangle, F C D E, within which is placed a glass jar, G H, containing mercury, and serving as the bulb of the pendulum. When the weather becomes warm, the steel rod and rectangle elongate, and therefore depress the centre of oscillation. But simultaneously the mercury expands, and this motion takes place necessarily in the upward direction. If the quantity of mercury is properly adjusted, the centre of oscillation is carried as far upward by the mercurial expansion as downward by that of the steel. Its actual position remains, therefore, the same; and as the length of the pendulum is the distance between the point of suspension and centre of oscillation, that length remains unchanged. The gridiron pendulum acts on similar principles.

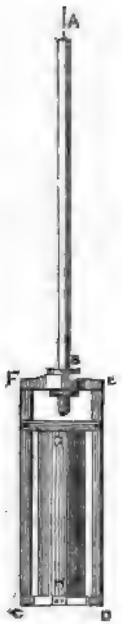


Fig. 138.

[The gridiron pendulum was contrived by Mr. Harrison, the inventor of the chronometer. It consists of a frame of nine parallel bars of steel and brass, arranged and connected as in the annexed figure. The bars marked *s* are steel, the four marked *b* are of brass; the centre rod, of steel, is fixed to the cross-bar connecting the two middle brass rods, but slides freely through the two lower bars, and bears the bob, *b*. The remaining rods are fastened to the cross pieces at both ends, and the uppermost cross piece is attached to the axis of suspension. It is easy to see, from the mere inspection of the figure, that the expansion of the steel rods tends to lengthen the pendulum, while that of the brass rods tends to shorten it: consequently, if the two expansions exactly counteract each other, the length of the pendulum will remain unchanged. The relative lengths of the brass and steel bars are determined by the expansion of the two metals, which is found by experiment to be, in general, nearly as 100 to 61. If, *then, the lengths* of all the five steel bars added *together be 100* inches, the sum of the lengths of the

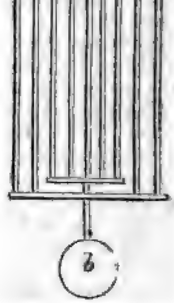


Fig. 139.

four brass bars ought to be 61 inches. When the compensation is found on trial not to be perfect, an adjustment is made by shifting one or more of the cross pieces higher on the bars.—*Brande's "Dictionary of Science, Literature, and Art."*]

The pendulum is also used to determine the force of gravity. The nature of this application has already been pointed out in what has been said respecting oscillations at the equator and the poles. The force of gravity at any place, or the height through which a body will fall in one second, is determined by multiplying the lengths of a seconds' pendulum for that place by the number 49·348.

The length of the seconds' pendulum being always invariable at the same place—for gravity is always invariable—may be used as a standard of measure. Thus, the English inch is of such a length that 39·13939 inches are equal to the length of a pendulum vibrating seconds. From these measures of length measures of capacity might be derived by taking their cubes, and measures of surface by taking their squares.

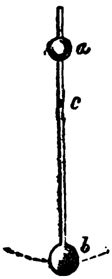


Fig. 140.

[A pendulum may have its centre of oscillation considerably beyond the limits of its actual dimensions, and a pendulum only one foot in length may be made to oscillate as slowly as another 12 feet long. Suppose a rod of iron, *a b*, to be loaded at both ends, and suspended at *c*, so that it might vibrate freely, it is manifest that though the arc described in each vibration would be limited by the length measured from the point of suspension, the velocity of the ball, *b*, would be checked by the counter-weight of the ball, *a*, and the latter being movable on the rod, the rate of vibration might be regulated at pleasure. —*Moffatt's "Boy's Book of Science."*

[The metronome is an example of this kind of pendulum.]

CHAPTER XXVI.

OF PERCUSSION.

Of Impact, Central, Eccentric, Direct, Oblique — Inelastic and Elastic Bodies—Laws of Collision of Inelastic Bodies—Changes of Figure of Elastic Bodies—Phenomena of their Collision—Of Reflected Motions.

IMPACT or percussion may take place in several different ways—as central, eccentric, direct, oblique.

Central impact takes place when the bodies in collision have their centre of gravity moving in the same right line.

Eccentric impact is when the directions of the motion of the centre of gravity of the bodies in collision make an angle with one another.

Direct impact is when the direction of the moving body is perpendicular to the surface on which it impinges.

Oblique impact is when the direction of the moving body makes some angle other than a right one with the surface on which it impinges.

The phenomena of percussion depend greatly on the physical character of

the impinging bodies. The bodies may either be inelastic or elastic. Masses of clay or putty are illustrations of the former case, balls of ivory or steel of the latter.

It has already been shown, Chapter XVII., that if two inelastic bodies move in the same direction, their joint momentum, after impact, is equal to the sum of their separate momenta; and that, if they move in opposite directions, it is equal to the difference. Their velocity, after impact, is found by dividing their common momentum by the sum of their masses.

When a hard body impinges on an immovable mass, the particles of which can, however, recede, so as to admit the impinging body, the depths to which it will penetrate are as the squares of its velocity multiplied by its mass.

When elastic bodies impinge on each other, there is, during the time of their encounter, a change of figure. Thus, if we take the instrument, Fig. 141, and, having painted one of its ivory balls, *a*, let the other ball, *b*, touch it gently, the latter will receive on its surface a single point of paint. But if we raise this ball, and let it fall from a considerable distance upon the other, it will receive a circular mark of paint, showing that, during the percussion, the balls lost their spherical figure, and, instead of touching by a single point, they touched by a surface of considerable extent. Their instantaneous recovery of the spherical form, like the facility with which that form was lost, is due to their elasticity.

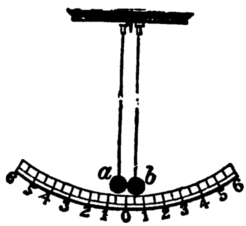


Fig. 141.

Whatever tends to impair the elasticity of such balls tends, therefore, to change the phenomena of impact. Thus, if we make a cavity in one of them, and fill it partially with lead, the balls, after percussion, will not recede from one another as far as before.

The manner in which elasticity acts in these cases may be understood by considering the action of a spiral spring between the two balls, the length of it coinciding with the direction of their motion. When the balls fall upon its extremities they give rise to compression, and the spring continually resists them at each successive instant. Their force, which was greatest at the moment of impact, is gradually overcome by the resistance of the spring, and finally vanishes. As soon as their velocity ceases, the spring can undergo no further compression, and is now able to begin to restore itself with a continually increasing force. Finally, it communicates to the balls the same velocity with which they originally impinged upon it.

When, therefore, a pair of elastic spherical balls are made to impinge on each other, there is a compression of their particles in the direction in which the motion is taking place, so that the diameters, *a b*, Fig. 142, are less than before. A spheroidal form is, therefore, the necessary result. But just as with the imaginary spring in the foregoing case, so with the compressed particles in this. As soon as the motion of the bodies becomes 0, the elastic force of the compressed particles gives rise to movement in the opposite direction.

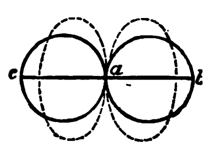


Fig. 142.

When two perfectly elastic bodies come in collision, the force of elasticity is equal to the force of compression, and the force of compression is equal to the force of the shock.

When two elastic bodies have struck each other, their recession will be with the same *relative* velocity with which they fell upon each other.

When two equal elastic bodies move toward each other with equal velocities, after percussion they recede from each other with the same velocity.

When of two equal elastic bodies one is in motion and the other at rest, the former, after collision, will communicate to the other all its velocity, and remain at rest itself. This phenomenon, and indeed much that is here said in relation to the impact of bodies, is well shown by an apparatus, such as Fig. 141, in which let the ball, *a*, be at rest, and let *b* fall on it from any height, after collision *a* takes the whole velocity of *b*, and *b* itself remains at rest.

When, of two equal bodies moving in the same direction, one overtakes the other, they exchange velocities, and go on as before.

When, two equal bodies moving with different velocities, encounter each other, they exchange, and recede from one another in contrary directions.

If, in the instrument, Fig. 141, instead of having only two ivory balls, we had a large number suspended, so as to touch one another, it would be found, on letting the ball at one extremity impinge on the other, that all the intermediate ones would remain motionless, and the one at the farther extremity would rebound.

[Fig. 143 represents a bar of wood supported at both ends, and having six small balls of ivory suspended from it, *a b c d e f*, by silk cords. If we remove the ball, *a*, and allow it to impinge or strike against the ball, *b*, the whole line will not move forwards, but will appear to act only on the ball, *f*, at the other end of the row, causing it first to separate from the rest, and to be moved in the same direction as the ball which communicated the motion; viz., from the position of *f* to *f'*. The ball, *f'*, will, in turn, impinge on the ball, *e*, and cause the ball, *a*, to be separated to the distance of *a'*, which is not quite so great as *f'* from its original position of *f*. If we use any number of balls, the same thing takes place, and if we allow two balls from either end to impinge upon the others, we shall find that two balls are propelled from the opposite end; for example, *a b* would separate *e f* from the others.]

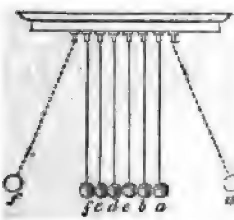


Fig. 143.

The motion, therefore, is transmitted through the entire series of balls; and it is the mutual reaction of the intermediate ones which keeps them at rest, the distant one rebounding because there is nothing against which it can react.

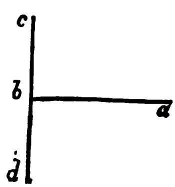


Fig. 144.

When an elastic ball strikes upon an immovable elastic plane, it will recoil with the same velocity with which it advanced. When the impact is perpendicular, the path of retrocession is the same as that of advance. Thus, if *a b*, Fig. 144, be the path of

the advance, perpendicular to *c d*, the elastic plane, the recoil or retrocession will be in the same path, but in the opposite direction, *b a*.

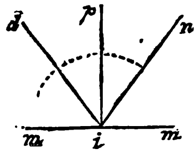


Fig. 145.

When the path of the striking body is not perpendicular, but at some other angle to the elastic plane, the recoil will be under the same angle, but on the opposite side of the perpendicular. Thus, if *n i*, Fig. 145, be the path of the striking body, *m m* the elastic plane, the path after contact will be *i d*, such that the points, *n i d*, are in the same plane, and the angle, *n i p*, is equal to the angle, *d i p*. To the former of these the name "angle of incidence" is given; to the latter, "angle of reflection."

The angle of incidence is the angle included between the path of the impinging body and a perpendicular drawn to the surface of impact at the point of impact. And the angle of reflection is the angle included between the path of the retroceding body and the same perpendicular.

The principles given in this chapter are applied in many cases of practice. Thus, in the pile-engine, which consists of a heavy block raised slowly by machinery between two uprights, and then allowed to fall suddenly on the head of the pile to be driven into the ground, if the block thus used as a hammer is too small, it fails to move the pile; and if its velocity is too great, it splits the head of the pile. A large mass, falling from a small height, is therefore used. Thus, it may be readily shown, that if the hammer weighs 1,000 pounds, and it falls through a height of only four feet, the force with which it strikes the pile is equal to 120,000 pounds.

When gold is beaten into thin leaves, the workmen cannot employ light hammers and use them quickly, for they would divide or fissure the gold; they use, therefore, heavier hammers, and move them more slowly.

SECTION V.—The Elements of Machinery.

CHAPTER XXVII.

THE MECHANICAL POWERS.

Definition of Machines—Number of Mechanical Powers—Power—Weight—Principle of Virtual Velocities—Definition of the Lever—Three kinds of Lever—Conditions of Equilibrium—Uses of Levers—The Balance—Weighing Machines.

By machines are meant certain contrivances employed for the purpose of changing the direction of moving powers, or of enabling them to produce any required velocity, or to overcome any required force.

It is to be understood that the force of any moving power can never be increased by the agency of any machine, the duty of which is to transmit

the effect of that power unimpaired to the working point. Machinery cannot create power—it transmits it. Theoretically this transmission is supposed to take place without loss, but practically there is always a certain degree of diminution arising both from imperfections of construction, and the agency of such impediments to motion as friction, rigidity, &c., the consideration of which we shall resume in its proper place.

In what follows it will, therefore, be understood that we speak of the action of machines theoretically, and apart from the intervention of these disturbing causes.

All machines, no matter how complex soever their construction may be, can be reduced to one or more of six simpler elements, which pass under the name of the "mechanical powers:" they are the

Lever.	Wheel and Axle.	Wedge.
Pulley.	Inclined Plane.	Screw.

These mechanical powers, or simple machines, may, indeed, be further reduced to three: the

Lever.	Pulley	Inclined Plane.

In any machine the force or original prime mover passes under the name of THE POWER.

The resistance to be overcome, or that upon which the power is brought to bear through the intervention of the machine, goes under the name of THE WEIGHT.

The general law which determines the equilibrium of all machines, whether simple or compound, is as follows: "The power multiplied by the space through which it moves in a vertical direction is equal to the weight multiplied by the space through which it moves in a vertical direction." The principle involved in this law passes under the name of "the principle of virtual velocities."

The foregoing principle expounding the conditions under which the power and weight are in equilibrium, and the machine, therefore, in a state of rest, it follows, therefore, that "if the product arising from the power multiplied by the space through which it moves in a vertical direction, be greater than the product arising from the weight multiplied by the space through which it moves in a vertical direction, the power will overcome the resistance of the weight, and motion of the machine will ensue."

THE LEVER.

The lever is the first of the elementary machines. In theory, it is an inflexible and imponderable line, supported on one point on which it can turn. In practice, it consists of a solid unyielding rod, working upon a point called a fulcrum.

Three varieties of levers are commonly enumerated. In the first, the fulcrum is between the power and the weight. [We see examples of this kind of lever every day. If we use a pin to extract a periwinkle from its

shell, the pin is a lever of this class, the shell the fulcrum, and our fingers the power. If we poke the fire, the poker, A, is the lever, the bar, B, upon which it rests, is the fulcrum, the coals, C, the weight to be raised, and the hand, D, the power which raises it. The brake of a pump is a lever of this class; the piston and the pump-rods being the weight to be raised, and the fulcrum the point on which it turns. A common claw-hammer, used to raise a nail from a piece of wood, is another familiar example; the hand, *a*, being the power, the wood, *f*, the fulcrum, and the nail, *n*, the resistance to be overcome. All instruments for cutting or holding, which are composed of two pieces crossing each other in the middle, such as scissors, shears, pincers, pliers, nippers, &c., are familiar examples; the pivot or joint being the fulcrum, the resistance or weight the paper, grass, &c., to be cut or seized, and the power applied by the hand. A common crowbar, applied to raise stones or other weights, is another familiar example; the fulcrum being another stone placed near to the one to be raised, and the power the man's hand who raises it.] In the second, the weight is between the power and the fulcrum, Fig. 148. [The oar, which urges a boat forward, is an excellent example of this kind of lever; the blade forced against the water being the fulcrum, the boat the weight, and the man's hand the power. The rudder of a ship acts in the same manner; and when we open a door, the hinge is the fulcrum, the air the resistance, and our hands the power. The common wheelbarrow is another example, the fulcrum being the point at which the wheel presses on the ground, the weight being the barrow and its load, while the power is represented by the two handles which the man lifts, and in proportion as he lengthens or shortens his hold on the handles, so is the power greater or less. The old sugar-chopper used by grocers is a very good example of a lever of the second kind, Fig. 149; the hinge, F, being the fulcrum, the sugar, W, the weight or resistance, and the handle, P, the power. Nut-crackers, and cork or lemon squeezers, belong to this class. Two men carrying a sedan-chair is another example, and so is a pair of bellows. When a crowbar is placed underneath a stone, and the end of the bar raised, it becomes a lever of the second kind, the end resting on the ground being the fulcrum, the stone the resistance, and the upward movement of the man's hand the

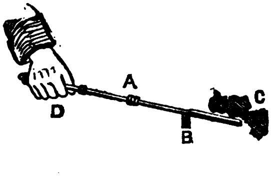


Fig. 146.

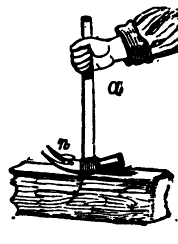


Fig. 147.

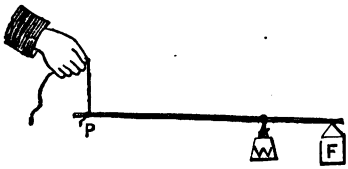


Fig. 148.

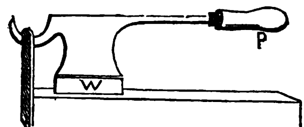


Fig. 149.

power.] In the third, the power is between the weight and the fulcrum, Fig. 150. [This kind of lever possesses certain advantages over the two former, because what is lost in power is gained in velocity, a small power causing the long arm of the lever to move over a great space. Of course, when we say that what is lost in power is gained in velocity, we only speak comparatively.

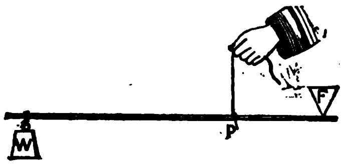


Fig. 150.

A familiar example of this class is a man using a flail with both hands. The treadle of a turning-lathe is another example: the end which rests on the ground is the fulcrum, the foot of the man which presses on the board, near the fulcrum, is the power, and the crank upon the axis of the fly-wheel, which is attached to the other end, is the weight. The most interesting examples of the application of this class of levers are to be found in the structure of animals, particularly the arm and fore-arm of man, and the lower jaw, as shown in Figs. 151 and 152. In the former, the lower end of the arm-bone, *a*, becomes the fulcrum, the bones of the fore-arm, *c*, *b*, the lever, and the *biceps flexor cubiti*, *d*, or the muscle, which bends the

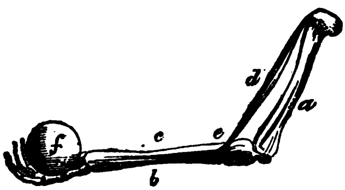


Fig. 151.

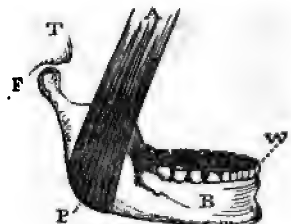


Fig. 152.

fore-arm, and is inserted at *e*, into the posterior part of the tubercle of the radius, is the power which raises the weight, *f*, held in the hand. The fulcrum, F, of the lower jaw, B, is formed by the *condyle*, or end of the bone, which rests against the temporal bone, T, while the resistance or weight, W, is at the opposite end, and acted upon by the *masseter* muscle, A, placed at the angle of the jaw-bone.] There are also other species of lever, such as the bent lever, the curvilinear lever. The mode of action and theory of all are the same. [The same advantage cannot be derived from a bent lever as from a straight one of the same length. Let A B, Fig. 153, represent a curved lever, which is supported at F, having the weight, W, attached at B, and the power, P, applied at E. If we wish to find the momentum of the weight, we have only to multiply its weight by the ideal lines, A F, or B C; and the momentum of power will be found by multiplying its weight by the ideal lines D E, or F G.]

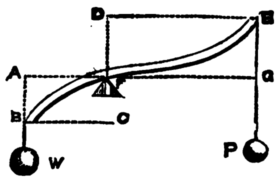


Fig. 153.

By the principle of virtual velocities it appears that "any lever is in equilibrio when the power and the weight are to each other inversely as their distances from the fulcrum."

As illustrative instances of this—if, in a lever of the first kind in equilibrio, the power and the weight are equal, they must be at equal distances from the fulcrum; if the power is only half the weight, it must be at double the distance from the fulcrum; if one-third the weight, triple the distance, &c.

When, therefore, it is proposed by the intervention of a lever to cause a given power to overcome a given weight, it is necessary that the power multiplied by its distance from the fulcrum should give a greater product than the weight multiplied by its distance from the fulcrum. Thus, in Fig. 154, let P be a power of six pounds, operating on a lever of the first kind, at a distance, P *c*, from the fulcrum, *c*, of seven inches; let W be the weight to be overcome, and let it be seven pounds, with a distance, W *c*, of six inches from the fulcrum. Now the power multiplied into its distance is equal to forty-two, and the weight multiplied into its distance is also equal to forty-two; the lever is, therefore, under the law just stated, in equilibrio. But if we increase the distance of P from *c*, or increase P itself, or do both, then the product of P into its distance from the fulcrum will increase, the lever will move, and the resistance of the weight be overcome.

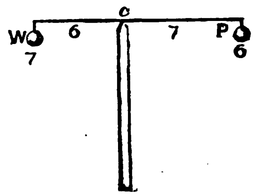


Fig. 154.

Levers are used in practice for many different purposes. By their agency a small power may hold in equilibrio or move a great weight: thus, the power of one man applied at the end of a crowbar will overturn a heavy mass, the man acting at a distance of several feet, and the mass at only a few inches from the fulcrum.

[Levers are sometimes compound, or made up of several simple levers connected together, so as to act one upon the other. For example, suppose we wish to have a very long lever, or one possessing great mechanical power, it is easier to arrange a series of levers, so that the power acting on the end of the first lever shall raise the second, and that, depressing the end of the third, will raise a weight at the further end. For example, suppose that we wish to balance 1,000 pounds by means of one pound, the distance of the power from the fulcrum must be 1,000 times that of the weight, and as this would be very inconvenient, we employ three levers for the purpose of obtaining the same result. The relative length of the arms of each lever is as ten to one; and if we examine Fig. 155, we shall see that the levers are so arranged as to bear upon one another. Thus, the power of one pound will balance the weight of ten pounds; and as the weight end of the first lever is placed under the power end of the second lever, it will exercise a force of ten pounds upon it. The second lever being raised with a force of ten pounds, and having the same mechanical advantage as the first, will press down the weight end upon the power end of the third with a force equal to 100 pounds.

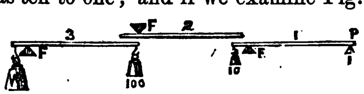


Fig. 155.

This force of 100 pounds, being applied to the power end of the third lever, will act upon the same principles as the others, and raise the weight end with a force of 1,000 pounds.

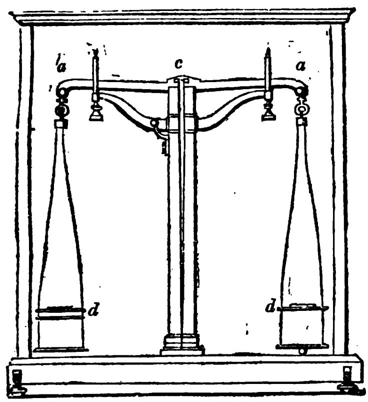


Fig. 156.

[In calculating the action of any compound system of levers, it does not affect the principles of calculation if some of the levers are of the first kind, and some of any other. The rule is to "multiply the weight on any lever by its distance from the fulcrum, and multiply the power by its distance from the same point; if the products are equal, then the weight and power will balance each other." If we wish to calculate the effect of the system given in Fig. 155, we must multiply the length of the long arm by the power, and multiply the short arm by the weight or resistance offered.]

For many of the purposes of science, levers are used to magnify small motions. The power causing the motion is applied by a short arm near to the fulcrum of the lever; and the other arm, which may be ten, twenty, or more times longer, moves over a graduated scale. The pyrometer is an example of this application.

The most accurate means of determining the weight of bodies is by the lever. When arranged for this purpose, it passes under the name of "The Balance." It is a lever of the first kind with equal arms. Various forms are given to it, and various contrivances annexed for the purpose of insuring its lightness, its inflexibility, and the absolute equality of the lengths of its arms. Fig. 156 represents one of the best kinds: *a a* is the beam; *c* is the fulcrum, or centre of motion; *d d* are the scale-pans, in which the weights and objects to be weighed are applied; their points of suspension are at *a a*. With a view of reducing friction, the axis of motion, *c*, and both the points of suspension, are knife-edges of hard steel, working on planes of agate; and to preserve them uninjured, the beam and the scale-pans are supported upon props, except at the time a substance is to be weighed. Then, by moving the handle, *f*, the axis of motion is deposited slowly on its agate plane, and the scale-pans on their points of suspension, and the beam thrown into action.

In balances it is essential that the centre of gravity should have a particular position. The cause of this will be appreciated from what has been said in Chapter XXIV. Thus, if the centre of gravity coincided with the centre of motion, the balance beam would not vibrate, but would stand in a position of different equilibrium, whatever angular position might be given to its arms.

If the centre of gravity was above the axis of motion, the balance would be in a condition of unstable equilibrium, and would overset by the slightest increase of weight on either side, the centre of gravity coming down to the lowest point. But when it is beneath the axis of motion, the balance vibrates like a pendulum, and neither sets nor oversets. It is essential,

therefore, that in all these instruments the centre of gravity should be below the centre of motion. And it might be shown that the sensibility of the balance, or, in other words, the smallness of the weight it will detect, becomes greater as these two centres approach each other.

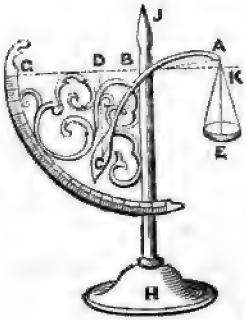


Fig. 157.

The different kinds of weighing-machines are either modified levers or combinations of levers. Examples occur in the machine for weighing loaded carts, in the steelyard, which is a lever of unequal arms, and in the bent lever balance. The latter is represented in Fig. 157. It consists of a bent lever, A B C, the end of which, C, is loaded with a fixed weight. This lever works on a fulcrum, B, supported on a pillar, H, J. From the arm, A, is suspended a scale-pan, E, and to the pillar there is affixed a divided scale, F G, over which the lever moves. Through B draw the horizontal line, G K, and let fall from it the perpendiculars, A K, D C. Then if B K and B D are inversely proportional to the weight in the scale, E, and the fixed weight, C, the balance will be in equilibrio; but if they are not, then the lever moves, C going farther from the fulcrum, and stopping when equilibrium is attained. The scale, F G, is graduated by previously putting known weights in E.

CHAPTER XXVIII.

THE PULLEY—THE WHEEL AND AXLE.

Description of the Pulley—Laws of the Lever apply to it—Use of the Fixed Pulley—The Movable Pulley—Runners—Systems of Pulleys—White's Pulley—Law of Equilibrium—Advantages of the Wheel and Axle over the Lever—Windlass—Capstan—Wheelwork—Different kinds of Toothed Wheels.

THE pulley is a wheel, round the rim of which a groove is cut, in which a cord can work, and the centre of which moves on pivots in a block. The wheel sometimes passes under the name of a sheave.

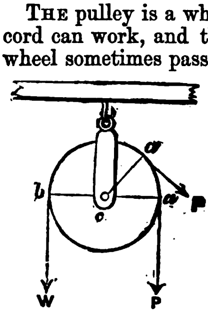


Fig. 158.

By a fixed pulley, we mean one which merely revolves on its axis, but does not change its place. The power is applied to one end of the cord, and the weight to the other.

The action of the pulley may be readily understood from that of the lever. Let c, Fig. 158, be the axis of the pulley; b, the point to which the weight is attached; a, the point of application of the power; draw the lines, $c\ b$, $c\ a$—they represent the arms of a lever—and the law of the equilibrium of a lever, therefore, applies in this case also; and as these arms are necessarily equal to each other, the pulley will be in equilibrio when the weight and power are equal.

If the direction in which the power is applied, instead of being P a, is P′ a', the same reasoning holds good. For, on drawing C a', as before, it is obvious that b c a represents a bent lever of equal arms. The condition of equilibrium is, therefore, the same.

The fixed pulley does not increase the power, but it renders it more available, by permitting us to apply it in any desired direction.

To prove the properties of the pulley experimentally, hang to the ends of its cord equal weights; they will remain in equilibrio. Or, if the power be increased, so as to make the weight ascend, the vertical distances passed over are equal.

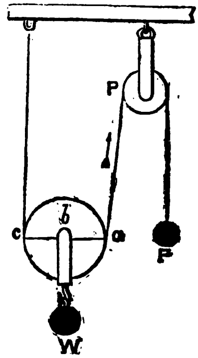


Fig. 159.

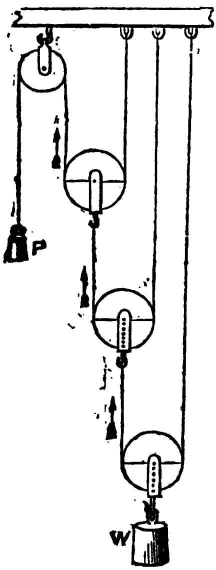


Fig. 160.

The movable pulley is represented at Fig. 159. Its peculiarity is that, besides the motion on its own axis, it also has a progressive one. Let b be the axis of the pulley, and to it the weight, W, is attached; the power is applied at a. Draw the diameter, a c, then c is the fulcrum of a c, which is in reality a lever of the third order, in which the distance, a c, of the power is twice that, b c, of the weight. Consequently "the movable pulley doubles the effect of the power," and the distance traversed by the power is twice that traversed by the weight.

A movable pulley is sometimes called "a runner;" and as it would be often inconvenient to apply the power in the upward direction, as at a P, there is commonly associated with the runner a fixed pulley, which, without changing the value of the power, enables us to vary the direction of its action.

Systems of pulleys are arrangements of sheaves, movable and fixed.

When one fixed pulley acts on a number of movable ones, equilibrium is maintained when the power and weight are to each other as 1 to that power of 2 which equals the number of the movable pulleys. Thus, if there be, as in Fig. 160, three movable pulleys, the power is to the weight as $1 : 2^3$ that is, $1 : 8$; consequently, on such a system, a given power will support an eightfold weight.

When several movable and fixed pulleys are employed, as in Fig. 161, equilibrium is obtained when the power equals the weight divided by twice the number of movable pulleys. The weight being equally divided between the six lines, it follows that each is drawn by $\frac{1}{6}$th of the weight, W. Consequently, if sixty pounds weight is suspended to the bottom, each line would be drawn upon by a force of ten pounds. If we wish to keep this machine in a state of equilibrium, we must attach a weight, P, of ten pounds to the end of the line.

In such systems of pulleys there is a great loss of power arising from the friction of the sheaves against the sides of the blocks, and on their axles.

In White's pulley this is, to a considerable extent, avoided. This contrivance is represented in Fig. 162. It consists of several sheaves of unequal diameters, all turned on one common mass, and working on one common axis. The diameters of these, in the upper blocks, are as the numbers 2, 4, 6, &c.; and in the lower, 1, 3, 5, &c.; consequently they all revolve in equal times, and the rope passes without sliding or scraping upon the grooves.

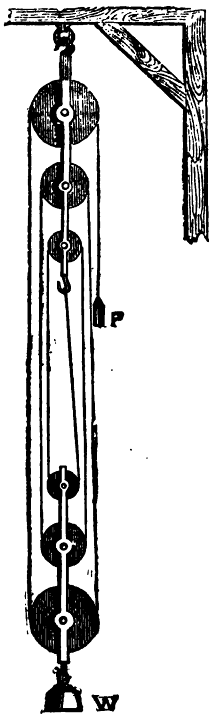


Fig. 161.

WHEELS AND AXLES.

The wheel and axle consist of a cylinder revolving upon an axis, and having a wheel of larger diameter immovably affixed to it. The power is applied to the circumference of the wheel, the weight to that of the axle.

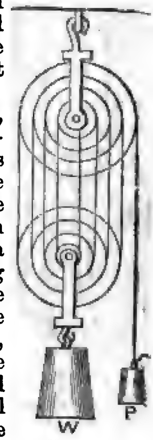


Fig. 162.

[Let *a b* be a wheel, *c d*, Fig. 163, its axle, and suppose the circumference of the wheel to be eight times as great as the circumference of the axle; then a power, P, equal to one pound, hanging by the cord, I, which goes round the wheel, will balance a weight, W, of eight pounds, hanging by the rope, K, which goes round the axle; and as the friction on the pivots, E F, or gudgeons of the axle, is but small, a small addition to the power will cause it to descend, and raise the weight; but the weight will rise with only an eighth part of the velocity wherewith the power descends, and consequently through no more than an eighth part of an equal space in the same time. If the wheel be pulled round by the handles, S S, the power will be increased in proportion to their length. G is a ratchet-wheel on one end of the axle, with a catch, H, to fall in its teeth.—*Ferguson's Lectures, 10th edition, page 55.*]

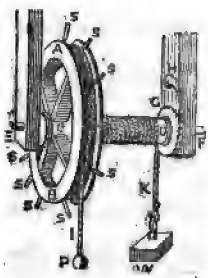


Fig. 163.

The law of equilibrium is, that "the power must be to the weight as the radius of the axle is to that of the wheel."

This instrument is, evidently, nothing but a modification of the lever; it may be regarded as a continuously acting lever; in fact, it is sometimes called "the perpetual lever." In its mode of action the common lever operates in an intermittent way, and, as it were, by small steps at a time. A mass which is forced up by a lever a short distance must be temporarily propped, and the lever re-adjusted before it can be brought into action again; but the wheel and axle continue their operation constantly in the same direction.

[The inconvenience of having a large wheel and very slender axle may be avoided, without lessening the mechanical advantage, by employing a machine called the "Chinese wheel and axle," which consists of two cylinders, one larger than the other, turning about the same axis. The weight is attached to a pulley, which plays on a long cord, which is coiled round both axles in contrary directions. When the winch is turned, one end of the cord uncoils from the smaller cylinder, and is wound round the larger; thus the weight is elevated at each turn, through a space equal to half of the difference between the circumference of the two cylinders. Therefore the advantage of this machine, with its pulley, is in the ratio of the diameter of the larger cylinder to half its excess above that of the lesser one.] (Fig. 164.)

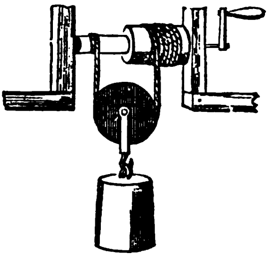


Fig. 164.

That this is its mode of action may be understood from considering Fig. 165, in which let c be the common centre of the axle, $c\,b$, and of the wheel, $c\,a$, a the point of application of the power, P, and b that of the weight, W. Draw the line $a\,c\,b$; it evidently represents a lever of the first order, of which the fulcrum is c, and from the principles of the lever it is easy to demonstrate the law of equilibrium of this machine, as just given. Further, it is immaterial in what direction the power be applied, as P′ at the point, a'; for $a'\,c\,b$ still forms a bent lever, and the same principle still holds good.

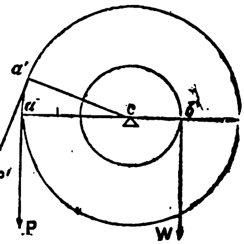


Fig. 165.

[The effect of the wheel depends upon the superiority of the radius, or diameter of the wheel, to that of the axle. In Fig. 166 we see that the weight, W, corresponds with the counteracting force, P, in an inverse ratio to the arms of the lever; that is, inversely to the radii, $a\,b$ and $d\,c$, of the wheel. Let us suppose that the radius, $a\,b$, of the axle is four times less than the radius, $d\,c$, of the wheel, we may equipoise a weight of eighty pounds by a force of twenty pounds.]

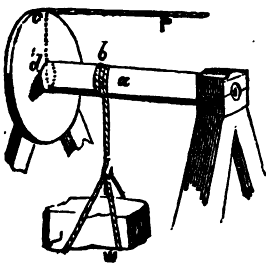


Fig. 166.

Sometimes the wheel is replaced by a winch, as in Fig. 167; it is then called a "windlass," if the motion is vertical; but if it be horizontal, as in Fig. 168, the machine is called a "capstan," which differs from a windlass in having its revolving axis placed vertically. The circumference is pierced with holes, which receive long levers, called capstan-bars, by which it is worked by men, who walk round the capstan, and make it revolve by pressing the ends of the levers forward.

[The treadmill is another variety. In this case the weight of several people treading on the circumference of a long wheel causes it to revolve.

The paddle-wheel of a steamboat acts on the same principle; the water, which offers a resistance to the motion of the paddle-boards, is the power.]

Wheels and axles are often made to act upon one another by the aid of cogs, as in clockwork and mill machinery. In these cases the cogs on the periphery of the wheel take the name of teeth, those on the axle the name of leaves, and the axle itself is called a pinion.

The law of equilibrium of such machines may be easily demonstrated to be, that the power multiplied by the product of the number of teeth in all

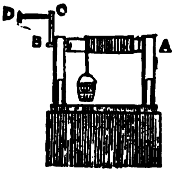


Fig. 167.

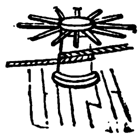


Fig. 168.

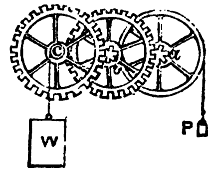


Fig. 169.

the wheels, is equal to the weight multiplied by the product of the number of leaves in all the pinions.

A system of wheel and pinion work is represented at Fig. 169. It is scarcely necessary to observe, that in it, as in all other cases, the law of virtual velocities holds good—the power multiplied by the velocity of the power is equal to the weight multiplied by the velocity of the weight.

In the construction of such machinery attention has to be paid to the form of the teeth, so that they may not scrape or jolt upon one another. Several of them should be in contact at once, to diminish the risk of fracture and the wear.

If the teeth of a wheel be in the direction of radii from its centre it is called a spur-wheel.

If the teeth are parallel to the axis of the wheel it is called a crown-wheel.

If the teeth are oblique to the axis of the wheel it is called a bevelled-wheel.

By combining these different forms of wheel suitably together, the resulting motion can be transferred to any required plane. Thus by a pair of bevelled-wheels motion round a vertical axis may be transferred to a horizontal one, or, indeed, one in any other direction.

When a pinion is made to work on a toothed bar, it constitutes a rack. This contrivance is under the same law as the wheel and axle.

CHAPTER XXIX.

THE INCLINED PLANE—THE WEDGE—THE SCREW.

Description of the Inclined Plane—Modes of applying the Power—Conditions of Equilibrium when the Power is Parallel to the Plane or Parallel to the Base—Position of Greatest Advantage—Description and Mode of using the Wedge—Formation of the Screw.

By the inclined plane we mean the unyielding plane surface inclined obliquely to the resistance to be overcome.

In Fig. 170, A C represents the inclined plane; the angle at A is the elevation of the plane; the line A C is the length, C B is the height, A B the base.

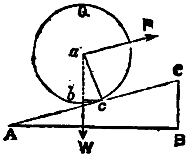


Fig. 170.

In the inclined plane the power may be applied in the following directions:—1. Parallel to the plane; 2. Parallel to its base; 3. Parallel to neither of these lines.

As in the former cases, so in this—the conditions of the equilibrium may be deduced from those of the lever.

Let us take the first instance, when the power is applied parallel to the inclined plane. Let Q, Fig. 170, be a body placed upon the plane, A C, the height of which is B C, and the base A B. The weight of this body acts in the vertical direction, *a* W; the body rests on the point, *c*, as on a fulcrum; and the power, P, under the supposition, acts on Q, in the direction *a* P. From the fulcrum, *c*, draw the perpendicular, *c b*, to the line of direction of the weight, *a* W; draw also *c a*. Then does *b c a* represent a bent lever, the power being applied to the point, *a*, and the weight at the point, *b*; and, therefore, the power is to the weight as *b c* is to *a c*; but the triangles, *a b c*, A B C, are similar to each other. Therefore we arrive at the following law:—

When the power acts in a direction parallel to the inclined plane, it will be in equilibrio with the weight when it is to the weight as the perpendicular of the plane is to its length.

In a similar manner it may be shown that when the power acts parallel to the base it will be in equilibrio with the weight, if it be to the weight as the perpendicular of the plane is to its base.

In different inclined planes the power increases as the height of the plane, compared with its length, diminishes, and the best direction of action is parallel to the inclined plane. This is very evident from the consideration that, if the power be directed above the plane, a portion of it is expended in lifting the weight off the plane, while the diminished residue draws it up. If it be directed downward a part is expended in pressing the weight upon the plane, and the diminished residue draws it up. Therefore, if the power acts parallel to the plane, it operates under the most advantageous condition.

The laws of the inclined plane may be illustrated by an instrument such as is represented in Fig. 171, in which A *c* A′ *c′* is the plane, which may be set at any angle. It works upon an axis, A A′. Upon the plane a roller, *e*, moves. It has a string passing over a pulley, *d*, and terminating in a scale-pan, *f*, in which weights may be placed. The direction of the string may be varied, so as to be parallel to the plane, or the base, or any other direction.

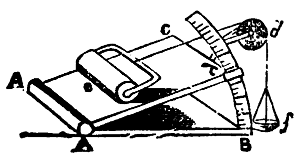


Fig. 171.

The inclined plane is used for a variety of purposes—very frequently for facilitating the movements of heavy loads

THE WEDGE.

The wedge may be regarded as two inclined planes laid base to base-

B D A, Fig. 172, being one, and B C A being the other. The planes, C A and D A, constitute the sides or faces of the wedge; B is its back, and B A its length.

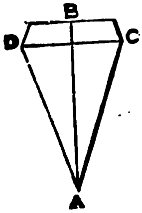


Fig. 172.

The mode of employing the wedge is not by the agency of pressure, but of percussion. Its edge being inserted into a fissure, the wedge, as in Fig. 173, is driven in by blows upon its back. After it has been struck for some time, the wedge enters further into the substance of the wood, as in Fig. 174, and when the wood cannot be compressed any more, the wedge splits it, as in Fig. 175. It is kept from recoiling by the friction of its sides against the surfaces past which it has been forced.

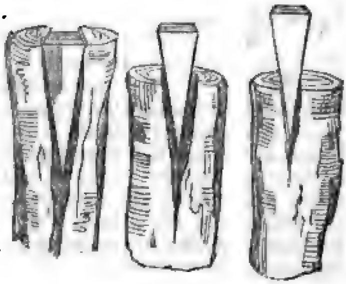


Fig. 175. Fig. 174. Fig. 173.

This mode of application of the wedge prevents us from comparing its theory with that of the inclined plane—a power to which it has so much external resemblance.

The power of the wedge increases as the length of its back, compared with that of its sides, is diminished. As instances of its application, we may mention the splitting of timber, the raising of heavy weights, such as ships. Different cutting instruments, as chisels, &c., act in consequence of their wedge-shaped form.

Fig. 176.

THE SCREW.

If we take a piece of paper cut into a long, right-angled triangle, Fig. 176, and wind it about a cylinder, Fig. 177, so that the height, C B, of the triangle is parallel to the axis, the length, A C, will trace a screw line on the surface. The same results if we take a cylinder and wind upon it a flexible cord, so that the strands of the cord uniformly touch one another.


Fig. 177.

In any screw the line which is thus traced upon the cylinder goes under the name of the "worm," or "thread," and each complete turn that it makes is called a "spire." The distance from one thread to another, which, of course, must be perfectly uniform throughout the screw, is called the breadth of the worm.

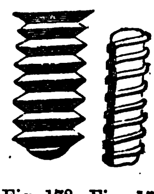


Fig. 178. Fig. 179.

[The thread of a screw may have a thin sharp edge, as in Fig. 178, or a square edge, as in Fig. 179. In either case the principle of its action is the same.

In most cases the screw requires a corresponding cavity in which it may work; this passes under the name of a "nut." Sometimes the nut is caused to move upon the screw, and sometimes the screw in the nut. In either case the movable part requires a lever to be attached, to the end of which the power is applied.

The law of equilibrium of the screw is, that "the power is to the weight as the breadth of the worm is to the circumference described by that point of the lever to which the power is attached."

When the end of a screw is advancing through a nut, this law evidently becomes that the power is to the weight as the circumference described by the power is to the space through which the end of the screw advances. It is obvious, therefore, that the force of the screw increases as its threads are finer, and as the lever by which it is urged is longer.

When the thread of a screw works in the teeth of a wheel, as shown in Fig. 180, it constitutes an endless screw. An important use of this contrivance is in the engine for dividing graduated circles. This screw is also used to produce slow motions, or to measure, by the advance of its point, minute spaces. In the spherometer, represented in Fig. 5, page 6, we have an example of its use.

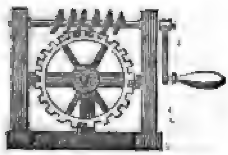


Fig. 180.

For all those purposes where slow motions have to be given, or minute spaces divided, the efficacy of the screw will increase with the closeness of its thread. But there is soon a practical limit attained; for, if the thread be too fine, it is liable to be torn off. To avoid this, and to attain those objects almost to an unlimited extent, Hunter's screw is often used. It may be understood from Fig. 181. It consists of a screw, working in a nut, *a b*. To a movable piece, *e*, a second screw, *c*, is affixed. This screw works in the interior of *a*, which is hollow, and in which a corresponding thread is cut. While, therefore, *a* is screwed downward, the threads of *c* pass upward, and the movable piece, *e*, advances through a space which is equal to the difference of the breadth of the two screws. In this way very slow or minute motions may be obtained with a screw, the threads of which are very coarse.

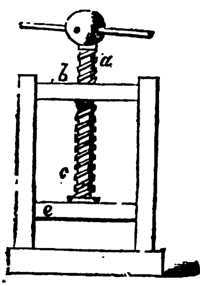


Fig. 181.

[Sometimes the lever is inserted into, or passes through, the nut into which the screw is inserted, as in Fig. 182. In this case the nut forces the screw upwards or downwards, according to circumstances.]

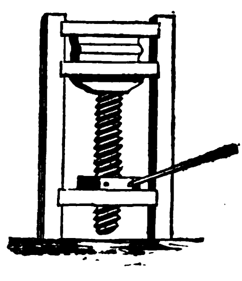


Fig. 182.

CHAPTER XXX.

OF PASSIVE OR RESISTING FORCES.

Difference between the Theoretical and Actual Results of Machinery—Of Impediments to Motion—Friction—Sliding and Rolling Friction—Co-efficient of Friction—Action of Unguents—Resistance of Media—General Phenomena of Resistance—Rigidity of Cordage.

It has already been stated, in the foregoing chapters, that the properties of machinery are described without taking into account any of those resisting agencies which so greatly complicate their action. The results of the theory of a machine in this respect differ very widely from its practical operation. There are resisting forces or impeding agencies which have thus far been kept out of view. We have described levers as being inflexible, the cords of pulleys as perfectly pliable, and machinery generally as experiencing no friction. In the case of one of the powers, it is true that this latter resisting force must necessarily be taken into account; for it is upon it that the efficacy of the wedge chiefly depends.

So, too, in speaking of the motion of projectiles, it has been stated that the parabolic theory is wholly departed from, by reason of the resistance of the air; and that not only is the path of such bodies changed, but their range becomes vastly less than what, upon that theory, it should be. Thus, a 24-pound shot, discharged at an elevation of 45° with a velocity of 2,000 feet per second, would range a horizontal distance of 125,000 feet were it not for the resistance of the air; but through that resistance its range is limited to about 7,300 feet.

Of these impediments to motion, or passive or resisting forces, three leading ones may be mentioned. They are, 1st, friction; 2nd, resistance of the media moved through; 3rd, rigidity of cordage.

OF FRICTION.

Friction arises from the adhesion of surfaces brought into contact, and is of different kinds—as *sliding friction*, when one surface moves parallel to the other; *rolling friction*, when a round body turns upon the surface of another.

By the measure of friction we mean that part of the weight of the moving body which must be expended in overcoming the friction. The friction which expresses this is termed the co-efficient of friction. Thus, the co-efficient of sliding friction in the case of hard bodies, and when the weight is small, ranges from one-seventh to one-third.

[We are not to consider friction as a *small* force, slightly modifying the effects of other agencies. On the contrary, its amount is in most cases very great. When a body lies loose on the ground the friction is equal to one-third or one-half, or in some cases of bodies supported by oblique pressure the amount is far more enormous. In the arch of a bridge, the friction which is called into play between two of the vaulting stones may be equal to the whole weight of the bridge. In such cases this conservative force is so great, that the common theory, which neglects it, does not help us even to guess what will take place. According to the theory, certain forms of arches only will stand; but in practice almost any form will stand, and it is not easy to construct a model of a bridge which will fall.

[We may see the great force of friction in the *brake*, by which a large weight running down a long inclined plane has its motion moderated and stopped; in the windlass, where a few coils of the rope round a cylinder sustain the stress and weight of a large iron anchor; in the mode of raising large blocks of granite by an iron rod driven into a hole in the stone. Probably no greater forces are exercised in any processes in the arts than the force of friction; and it is always employed to produce rest, stability, moderate motion. Being always ready and never wearied, always at hand, and augmenting with the exigency, it regulates, controls, subdues all motions; counteracts all other agents; and, finally, gains the mastery over all other terrestrial agencies, however violent, frequent, or long-continued. The perpetual action of all other terrestrial forces appears, on a large scale, only as so many interruptions of the constant and stationary rule of friction. —"*Astronomy and General Physics*," *by Professor Whewell.*]

It has been proved by experiment that friction increases as the weight or pressure increases, and as the surfaces in contact are more extensive, and as the roughness is greater. With surfaces of the same material it is nearly proportional to the pressure. The time which the surfaces have been in contact appears to have a considerable influence, though this differs much with surfaces of different kinds. As a general rule, similar substances give rise to greater friction than dissimilar ones.

On the contrary, friction diminishes as the pressure is less, as the polish of the moving surfaces is more perfect, and as the surfaces in contact are smaller. It may also be diminished by anointing the surfaces with some suitable unguent or greasy material. Among such substances as are commonly used are the different fats, tar, and black-lead. By such means, friction may be reduced to one-fourth.

Of the friction produced by sliding and rolling motions, the latter, under similar circumstances, is far the least. This partly arises from the fact that the surfaces in contact constitute a mere line, and partly because the asperities are not abraded or pushed aside before motion can ensue. The nature of this distinction may be clearly understood by observing what takes place when two brushes with stiff bristles are moved over one another, and when a round brush is rolled over a flat one. In this instance, the rolling motion lifts the resisting surfaces from one another; in the former, they require to be forcibly pushed apart.

Though, in many instances, friction acts as a resisting agency, and diminishes the power we apply to machines, in some cases its effects are of the utmost value. Thus, when nails or screws are driven into bodies, with a view of holding them together, it is friction alone which maintains them in their places. The case is precisely the same as in the action of a wedge.

RESISTANCE OF MEDIA.

A great many results in natural philosophy illustrate the resistance which media offer to the passage of bodies through them. The experiment known under the name of the guinea and feather experiment establishes this for atmospheric air. In a very tall air-pump receiver there are suspended a piece of coin and a feather in such a way that, by turning a button, the piece on which they rest drops, and permits them to fall to the pump-plate. Now, if the receiver be full of atmospheric air, on letting the objects fall, it will be found that, while the coin descends with rapidity, and reaches in an instant the pump-plate, the feather comes down leisurely, being buoyed up

by the air, and the speed of its motion resisted. But if the air is first extracted by the pump, and the objects allowed to fall in vacuo, both precipitate themselves simultaneously with equal velocity, and accomplish their fall in equal times.

In the vibrations of a pendulum, the final stoppage is due partly to friction, and partly to this cause. And in the case of motions taking place in water, we should, of course, expect to find a greater resistance, arising from the greater density of that liquid.

The resisting force of a medium depends upon its density, upon the surface which the moving body presents, and on the velocity with which it moves.

Water, which is 800 times more dense than air, will offer a resistance 800 times greater to a given motion. Of the two mills represented in Fig. 35 (page 25), that which goes with its edge first runs far longer than that which moves with its plane first. We are not, however, to understand that the effect of the medium on a body moving through it increases directly as the transverse section of the body; for a great deal depends upon its figure. A wedge, going with its edge first, will pass through water more easily than if impelled with its back first, though, in both instances, the area of the transverse section is of course the same. It is stated that spherical balls encounter one-fourth less resistance from the air than would cylinders of equal diameter; and it is upon this principle that the bodies of fishes and birds are shaped, to enable them to move with as little resistance as may be through the media they inhabit.

The resistance of a medium increases with the velocity with which a body moves through it, being as the square of the velocity, so long as the motion is not too rapid; but when a high velocity is reached, other causes come into operation, and disturb the result.

As with friction, so with the resistance of media, a great many results depend on this impediment to motion; among such may be mentioned the swimming of fish through water, and the flight of birds through the air. It is the resistance of the air which makes the parachute descend with moderate velocity downward, and causes the rocket to rise swiftly upward.

RIGIDITY OF CORDAGE.

In the action of pulleys, in machinery in which the use of cordage is involved, the rigidity of that cordage is an impediment to motion. When a cord acts round a pulley, in consequence of imperfect flexibility, it obtains a leverage on the pulley, as may be understood from Fig. 183, in which let C K D be the pulley working on a pivot at O: let A and B be weights suspended by the rope, A C K D B. From what has been said respecting the theory of the pulley, the action of the machine may be regarded as that of a lever, C O D, with equal arms, C O, O D. Now, if the cord were perfectly inflexible, on making the weight, A, descend by the addition of a small weight to it, it would take the position at A′, the rope being a tangent to the pulley at C′; at the same time B, ascending, would take the position B′, its cord being a tangent at D′. From the new positions, A′ B′, which the inflexible cord is thus supposed to have assumed, draw the perpendiculars, A′ E, B′ F, then will O E, O F,

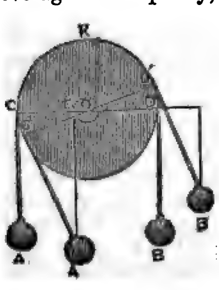


Fig. 183.

represent the arms of the lever on which they act—a diminished leverage on the side of the descending, and an increased leverage on the side of the ascending weight is the result.

In practice the result does not entirely conform to the foregoing imaginary case, because cords are, to a certain extent, flexible. As their pliability diminishes, the disturbing effect is greater. The degree of inflexibility depends on many casual circumstances, such as dampness or dryness, or the nature of the substance of which they are made. Inflexibility increases with the diameter of a cord, and with the smallness of the pulley over which it runs.

SECTION VI.—Undulatory Motions.

CHAPTER XXXI.

OF UNDULATIONS.

Origin of Undulations—Progressive and Stationary Undulation—Course of a Progressive Wave—Nodal Points—Three different kinds of Vibration—Transverse Vibration of a Cord—Vibrations of Rods—Vibrations of Elastic Planes—Vibrations of Liquids—Waves on Water—Law of the Reflection of Undulations—Applied in the case of a Plane, a Circle, an Ellipse, a Parabola—Case of a Circular Wave on a Plane—Interference of Waves—Inflection of Waves—Intensity of Waves—Method of Combining Systems of Waves.

When an elastic body is disturbed at any point, its particles gradually return to a position of rest, after executing a series of vibratory movements. Thus, when a glass tumbler is struck by a hard body, a tremulous motion is communicated to its mass, which gradually declines in force until the movement finally ceases.

In the same manner a stretched cord, which is drawn aside at one point, and then suffered to go, is thrown into a vibratory or undulatory movement; and, according as circumstances differ, two different kinds of undulation may be established: 1st, progressive undulations; 2nd, stationary undulations.

In progressive undulations the vibrating particles of a body communicate their motion to the adjacent particles; a successive propagation of movement, therefore, ensues. Thus, if a cord is fastened at one end, and the other is moved up and down, a wave or undulation, *m* D *n* E *o*, Fig. 184, is produced. The part, *m* D *n*, is the elevation of the wave, D being the summit, *n* E *o* is the depression, E being the lowest point, D *p* is the height, *q* E the depth, and *m o* the length of the wave.

But, under the circumstances here considered, the moment this wave has formed, it passes onward, and successively assumes the positions indicated at I, II, III. When it has arrived at the other end of the cord, it at once returns with an inverted motion, as shown at IV and V. This, therefore, is a progressive undulation.

Again, instead of the cord receiving one impulse, let it be agitated equally at equal intervals of time; it will then divide itself, as shown in Fig. 185, into equal elevations and depressions with intervening points, *m n*, which

are at rest. These are stationary undulations, and the points are called nodal points.

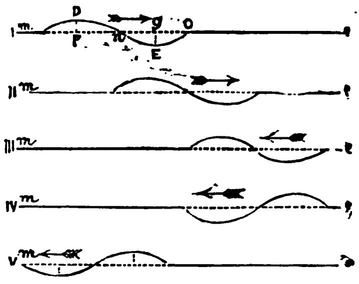
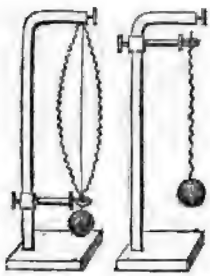


Fig. 184.

The agents by which undulatory movements are established are chiefly elasticity and gravity. It is the elasticity of air which enables it to transmit the vibratory motions which constitute sound, and, for the same reason, steel rods and plates of glass may be thrown into musical vibrations. In the case of threads and wires, a sufficient degree of elasticity may be given by forcibly stretching them. Waves on the surface of liquids are produced by the agency of gravity.

Fig. 185.

There are three different kinds of vibrations into which a stretched string may be thrown: transverse, longitudinal, and twisted. These may be illustrated by the instrument represented at Fig. 186. It consists of a piece of spirally-twisted wire, stretched from a frame by a weight. If the lower end of the wire be secured by a clamp, on pulling the wire in the middle, and then letting it go, it executes transverse vibrations, *a*. If the weight be gently lifted, and then let fall, the wire performs longitudinal vibrations; and if the weight be twisted round, and then released, we have rotatory vibrations, *b*.



a *b*

Fig. 186.

If we take a string, *a b*, Fig. 187, and having stretched it between two fixed points, *a* and *b*, draw it aside, and then let it go, it executes transverse vibrations, as has already been described. The cause of its motion, from the position we have stretched it to, is its own elasticity. This makes it return from the position, *a b c*, to the straight line, *a f b*, with a continually accelerated velocity; but when it has arrived in *a f b*, it cannot stop there, its momentum carrying it forward to *a d b* with a velocity continually decreasing. Arrived in this position, it is, for a moment, at rest; but its elasticity again impels it as before, but in the reverse direction, to *a f b;* and so it executes vibrations on each side of that straight line, until it is finally brought to rest by the resistance of the air. One complete movement, from *a c b* to *a d b* and back, is called a vibration, and the time occupied in performing it the time of an oscillation.

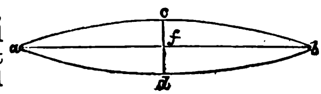


Fig. 187.

The vibratory movements of such a solid are isochronous, or performed in equal lines. They increase in rapidity with the tension—that is, with the elasticity—being as the square root of that force. The number of vibrations in a given time is inversely as the length of the string, and also inversely as its diameter.

The vibrations of solid bodies may be studied best under the division of cords, rods, planes, and masses. The laws of the vibrations of the first are such as we have just explained.

In rods the transverse vibrations are isochronous, and in a given time are in number inversely as the squares of the lengths of the vibrating parts. Thus, if a rod makes two vibrations in one second, if its length be reduced to half, it will make four times as many—that is, eight; if to one-fourth, sixteen times as many—that is, thirty-two, &c. The motion performed by vibrating rods is often very complex. Thus, if a bead be fastened on the free extremity of a vibrating steel rod, Fig. 188, it will exhibit in its motions a curved path, as is seen at *c*. Rods may be made to exhibit nodal points. The space between the free extremity and the first nodal point is equal to half the length contained between any two nodal points, but it vibrates with the same velocity. Thus *a*, Fig. 189, being the fixed, and *b* the free end of such a rod, the part between *b* and *c* is half the distance, *c c'*.

Fig. 188.

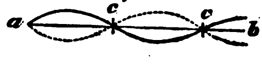


Fig. 189.

When elastic planes vibrate they exhibit *nodal lines*, answering to the nodal points in linear vibrations; and if the plane were supposed to be made up of a series of rods, these lines would answer to their nodal points. By them the plane is divided into spaces—the adjacent ones being always in opposite phases of vibrations, as shown by the signs + and — in Fig. 190, where A B is the vibrating plane. The dimensions of these spaces are regulated in the same way as the internodes of vibrating rods—that is, the outside ones, *a b a b*, are always half the size of the interior. The relation of these spaces, and positions of the nodal lines, may be determined by making a glass plate covered with dry sand vibrate.

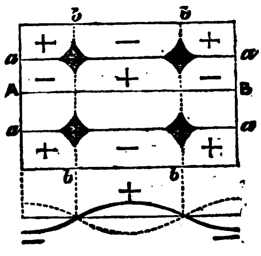


Fig. 190.

[When we wish to make plates vibrate we use a vice, such as is shown in Fig. 191, and having placed the plate between the cylinder, *a*, and the screw, *b*, both of which are tipped with leather or cork, the latter is turned until the plate is fixed firmly; and then, when a bow is drawn along the edge of the plate once or twice, it vibrates sufficiently to cause the sand upon its surface to rise and fall during the tone produced, and to accumulate upon the nodal lines, so as to form the sound-figures, as they were called by Chladui, their discoverer. These figures vary in form according as the bow is moved more or less rapidly or violently, and the point of support and action is changed.]

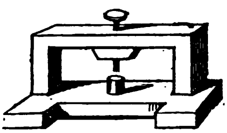


Fig. 191.

When the surface of a liquid, as water, is touched, a wave arises at the disturbed point, and propagates itself into the unmoved spaces around, continually enlarging as it goes, and forming a progressive undulation. [This is easily proved by filling a tumbler with water, and letting a small

piece of paper, a grain of corn, or any small object fall into it; or by throwing a stone into a smooth-surfaced pond.]

A number of familiar facts prove that the apparent advancing motion of the liquid on which waves are passing is only a deception. Light pieces of wood are not hurried forward on the surface of water, but merely rise up and sink down alternately as the waves pass. The true nature of the motion is such that each particle, at the surface of the undulating liquid, describes a circle in a vertical plane, and in the direction in which the wave is advancing, the movement being propagated from each to its next neighbour, and so on. And as a certain time must elapse for this transmission of motion, the different particles will be describing different points of their circular movement at the same moment. Some will be at the highest part of their vertical circle when others are in an intermediate position, and others at the lowest, giving rise to a wave, which advances a distance equal to its own length, while each particle performs one entire revolution.

[The force by which the water-waves are propagated is gravity; for, if from any cause an elevation or a depression be produced on the horizontal surface of the water, the gravity of the separate particles of water will endeavour to restore the disturbed horizontal plane, by which means an oscillatory motion is produced, which, by degrees, is propagated from one particle to another.—*Professor Müller's "Physics and Meteorology," Lecture* XV.]

Thus, in Fig. 192, let there be eight particles of water on the surface, *a m*, which, by some appropriate disturbance, are made to describe the vertical circles represented at *a b c d e f g h*, moving in the direction represented by the darts,

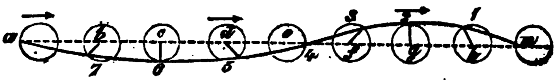


Fig. 192.

and let each one of these commence its motion one-eighth of a revolution later than the one before it. Then, at any given moment, when the first one, *a*, is in the position marked *a*, the second, *b*, will be in the position marked 7, *c* at 6, *d* at 5, *e* at 4, *f* at 3, *g* at 2, *h* at 1; but *m* will not yet have begun to move. If, therefore, we connect these various points, *a* 7 6 5 4 3 2 1 *m*, together by a line, that line will be on the surface of the wave, the length of which is *a m*, the height or depth of which is equal to the radius of the circle of each particle's revolution, and the time of passage through the length of one wave will be equal to the time of the revolution of each particle.

By a ray of undulation we mean a line drawn from the origin of a wave in the direction in which any given point of it is advancing. A wave is said to be incident when it falls on some resisting surface, and reflected when it recoils from it. Incident rays are those drawn from the origin towards the resisting surface, and reflected rays those expressing the path of the undulating points after their recoil. The angle of incidence is the angle which an incident wave makes with a perpendicular drawn to the surface of impact; the angle of reflection is the angle made by the reflected ray and the same perpendicular. Thus, let *s* be a resisting surface of any kind, *n i* an incident

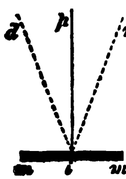


Fig. 193.

ray, *i p* a perpendicular to the point of impact of the wave, *i d* the reflected ray. Then *i p* is the angle of incidence, and *d i p* the angle of reflection.

The general law for the reflection of waves is, that "all the points in a wave will be reflected from the surface of the solid under the same angle at which they struck it."

If, therefore, parallel rays fall on a plane surface, they will be reflected parallel; if diverging, they will be reflected diverging; and if converging, converging.

If a circular wave advances from the centre of a circular vessel, each ray falls perpendicularly on the surface of the vessel, and is reflected perpendicularly—that is to say, back in the line along which it came. The waves, therefore, all return to the centre from which they originated.

If undulations proceed from one focus of an ellipse, they will, after reflection, converge to the other focus.

If a surface be a parabola, rays diverging from its focal point, *a*, will, after reflection, pass in parallel lines, *b d*, *c d*, *e d*. Or if the rays impinge in parallel lines, they will, after reflection, converge to the focus.

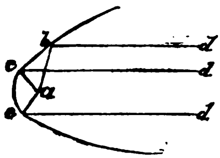


Fig. 194.

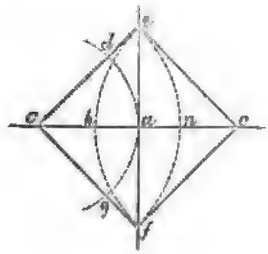


Fig. 195.

When diverging rays of a circular wave fall upon a plane surface, their path, after reflection, is such as it would have been had they originated from a point on the opposite side of the plane, and as far distant as the point of origin itself. Thus, let *c* be the origin of a circular wave, *d a g*, which impinges on a plane, *e f*, after reflection this wave will be found at *e h f*, as though it had originated at *c'*, a point on the opposite side of *e f*, as far as *c*, in front of it. Now, the parts of the circular wave, *d a g*, do not all impinge on the plane at the same time, but that at *a*, which falls perpendicularly, impinges first, and is first reflected; the ray at *d* has to go still through the distance, *d e*, before reflection takes place; but, in this space of time, the ray at *a* will have returned back to *h*; and, in the same way, it may be shown that the intermediate rays will have returned to intermediate positions, and be found in the line *e h f*, symmetrically situated, with respect to the line *e n f*, in which they would have been had they not fallen on the plane. And it further follows that the centre, *c'*, of the circular wave, *e h f*, is as far from *e f* as is the centre, *c*, of the circular wave, *e n f*, but on the opposite side.

By interference we mean that two or more waves have encountered one another, under such circumstances as to destroy each other's effect. If on water two elevations or two depressions coincide, they conspire; but when an elevation coincides with a depression, interference takes place, and the surface of the fluid remains plane. Waves which have thus crossed one another continue their motion unimpaired.

If two systems of waves of the same length encounter each other, after having come through paths of *equal* length, they will not interfere; nor will they interfere, even though there be a difference in the length of their paths, provided that difference be equal to one whole wave, or two, or three, &c.

But if two systems of waves of equal length encounter each other after

having come through paths of *unequal* length, they will interfere, and that interference will be complete when the difference of the paths through which they have come is half a wave, or one and a half, two and a half, three and a half, &c.

When a circular wave impinges on a solid in which there is an opening, as at *a b*, Fig. 196, the wave passes through, and is propagated to the spaces beyond; but other waves arise from *a b* as centres, and are propagated as represented at *c d e f*. This is the *inflection* of waves, and these new waves intersecting one another and the primitive one, give rise to interferences.

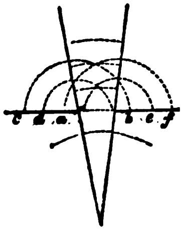


Fig. 196.

We have now traced the chief phenomena of vibrations in solids and on the surface of liquids. It remains to do the same for elastic bodies, such as gases.

When any vibratory movement takes place in atmospheric air, the impulse communicated to the particles causes them to recede a certain distance, condensing those that are before them; the impulse is finally overcome by the resistance arising from this condensation. There, therefore, arises a sphere of air, the superficies or shell of which has a maximum density. Reaction now sets in, the sphere contracts, and the returning particles come to their original positions. But as a disturbance on the surface of a liquid gives origin to a progressive wave, so does the same thing take place in the air.

By the intensity of vibration of a wave we mean the relative disturbance of its moving particles, or the magnitude of the excursions they make on each side of their line of rest. Thus, on the surface of water we may have waves "mountains high," or less than an inch high; the intensity of vibration in the former is correspondingly greater than in the latter case.

In aërial waves, precisely as in the surface waves of water, interference arises under the proper conditions. Thus, let *a m p h*, Fig. 197, be a wave

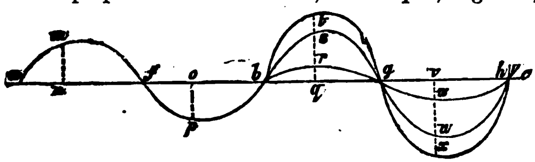


Fig. 197.

advancing toward *c*, and *m n o p* be the intensity of its vibration, or the maximum distances of the excursions of its vibrating particles. Then suppose a second wave, originating at *b* (a distance from *a* precisely equal to one wave length), the intensity of vibration of which is represented by *q r*. The motions of this second wave coinciding throughout its length with the motions of the first, the force of both systems is increased. The intensity, therefore, of the wave, arising from their conjoint action at any point, *q*, will be equal to the sum of their intensities, *q r*, *q s*—that is, it will be *q t*, and for any other point, *v*, it will be equal to the sum of *v w* and *v u*—that is, *v x*. So the new wave will be represented by *b t g x h*.

Now let things remain as before, except that the point of impact of the second wave, instead of being one whole wave from *a*, is only half a wave, the effects on any particle, such as *q*, take place in opposite directions, the second wave moving it with the intensity and direction *q r*, the first with *q s*—the resultant of its movement in intensity and direction will, therefore, be the difference of these quantities—that is, *q t*. And the same reasoning continued gives, for the wave resulting from this conjoint action, *b t g x h c*.

Under the circumstances given in Fig. 198, the systems of waves increase

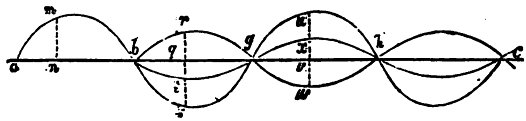


Fig. 198.

each other's force; under those of Fig. 197 they diminish it; or, if equal to one another, counteract completely, and total interference results.

Waves in the air, as they expand, have their superficies continually increasing, as the squares of their radii of distance from the original point of disturbance. Hence the effect of all such waves is to diminish as the squares of the distance increase.

SECTION VII.—The Laws of Sound.—Acoustics.

CHAPTER XXXII.

PRODUCTION OF SOUND.

The Note depends on Frequency of Vibration—Distinguishing Powers of the Ear—Soniferous Media—Origin of Sounds in the Air—Elasticity required and given in the Case of Strings by Stretching—Rate of Velocity of Sounds—All Sounds transmitted with Equal Speed—Distances determined by it—High and Low Sounds—Three Directions of Vibration—Intensity of Sound—Quality of Sounds—The Diatonic Scale.

When a thin elastic plate is made to vibrate, one of its ends being held firm in a vice, and the other being free, as in Fig. 199, and its length limited to a few inches, it emits a clear musical note. If it be gradually lengthened, it yields notes of different characters, and finally all sound ceases, the vibrations becoming so slow that the eye can follow them without difficulty.

This instructive experiment gives us a clear insight into the nature of musical sounds, and, indeed, of all sounds generally. A substance which is executing a vibratory movement, provided the vibrations follow one another with sufficient rapidity, yields a musical sound; but when those vibrations fall below a certain rate, the ear can no longer distinguish the effect of their impulsions.

The number of vibrations which such a plate makes in a given time depends upon its length, being inversely as the square of the length of the

vibrating part. Thus, if we take a given plate and reduce its length, the vibrations will increase in rapidity; when it is half as long it vibrates four times as fast; when one-fourth, sixteen times, &c.

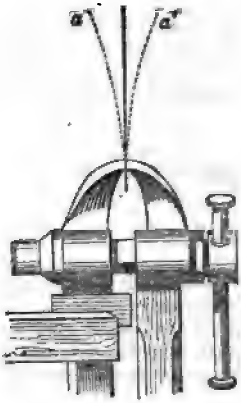


Fig. 199.

All sounds arise in vibratory movements, and musical notes differ from one another in the rapidity of. their vibrations—the more rapidly recurring or frequent the vibration the higher the note.

There is, therefore, no difficulty in determining how many vibrations are required to produce any given note. We have merely to find the length of a plate which will yield the note in question, knowing previously what length of it is required to make a determinate number of vibrations in a given space of time. Thus it has been found that the ear can distinguish a sound made by fifteen vibrations in a second, and can still continue to hear, though the number reaches 48,000 per second.

That all sounds arise in these pulsatory movements common observations abundantly prove. If we touch a bell, or the string of a piano, or the prong of a tuning-fork, we feel at once the vibratory action, and with the cessation of that motion the sound dies away.

But the pulsations of such a body are not alone sufficient to produce the phenomena of sound. Media must intervene between them and the organ of hearing. In most cases the medium is atmospheric air, and when this is taken away the effect of the vibrations wholly ceases. Thus, a bell, or a musical snuff-box, under an exhausted receiver, as we have already seen (Chapter VII., Fig. 38), can no longer be heard; but on re-admitting the air the sound becomes audible. The sounding body, therefore, requires a soniferous medium to propagate its impulses to the ear.

Atmospheric air is far from being the only soniferous medium. Sounds pass with facility through water; the scratching of a pin or the ticking of a watch may be heard by the ear applied at the end of a very long plank of wood. Any uniform elastic medium is capable of transmitting sound; but bodies which are imperfectly elastic, or have not an uniform density, impair its passage to a corresponding degree.

The effect of a vibrating spring, or, indeed, of any vibrating body on the atmospheric air, is to establish in it a series of condensations and rarefactions which give rise to waves. These, extending spherically from the point of disturbance, advance forward until they impinge on the ear, the structure of which is so arranged that the movement is impressed on the auditory nerves, and gives rise to the sensation which we term sound.

Both the sonorous body and the soniferous medium must, therefore, be elastic; the regularity of the pulsations of the former depends upon the uniformity of its elasticity. In the case of strings, we give them the requisite degree of elastic force by stretching them to the proper degree. And, as the undulatory movements which arise in the soniferous medium are not instantaneous, but successive, it follows that the transmission of sound in any

medium requires time. That this is the case, we may satisfy ourselves by remarking the period that elapses between seeing the flash of a gun and hearing the report. It is greater as we are removed to a greater distance. In different media, the velocity of transmission depends on the density and specific elasticity. It has been found, by experiment, that in tranquil air the velocity of sound at 60°, and at an average state of moisture, is 1,120 feet in a second. The wind accelerates or retards sound, according to its direction, damp air transmits it more slowly than dry, and hot air more rapidly than cold, the velocity increasing about 1·1 foot for every Fahrenheit degree.

In a soniferous medium, all sounds move equally fast; it is wholly immaterial what may be their quality, or their intensity. Thus, we know that even the most intricate music executed at a distance is heard without any discord, and precisely as it would be close at hand. Nor does it matter whether it be by the human voice, a flute, a bugle, or, indeed, by many different instruments at once; the relation of the difference of sounds is accurately preserved. But this can only take place as a consequence of the equal velocity of transmission; for if some of these sounds moved faster than others, discord must inevitably ensue.

The experiments of Colladon and Sturm on the lake of Geneva show that the velocity in water is about four times that in air, being 4,708 feet in a second. With respect to solid substances, it is stated that the velocity in air being one, that in tin is 7½, in copper 12, in glass 17.

Advantage is sometimes taken of these principles to determine distances. If we observe the time elapsing between the flash of a gun and hearing the sound, or between seeing lightning and hearing the thunder, every second answers to 1,120 feet.

Sounds are of different kinds: some are low or high, grave or acute, according as the vibrations are slower or faster. Again, the intensity of vibration, or the magnitudes of the excursions which the vibrating particles make, determine the force of sounds, an intense vibration giving a loud, and a less vibration a feeble sound.

The vibrations of a soniferous body may take place in three directions: they may be longitudinal, transverse, or rotatory vibrations; or, indeed, they may all co-exist. A body may be divided into vibrating parts, separated from one another by nodal points or lines. Thus, if we take a glass or metal plate, and having strewed its surface with fine dry sand, and holding it firmly at one point between the thumb and finger, or in a clamp, as represented in Fig. 200, draw a violin bow across its edge, it yields a musical note, and the sand is thrown off those places which are in motion, and collects on the nodal points, which are at rest.

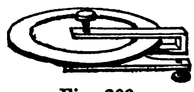


Fig. 200.

The *quantity*, or *strength*, or *intensity* of a sound depends on the intensity of the vibrations and the mass of the sounding body. It also varies with the distance, being inversely proportional to its square.

Musical sounds are spoken of as notes, or as *high* and *low*. Of two notes, the higher is that which arises from more rapid, and the lower from slower vibrations.

Besides this, sounds differ in their quality. The same note emitted by a flute, a violin, a piano, or the human voice, is wholly different, and in each

instance peculiar. In what this peculiarity consists we are not able to say.

The several notes are distinguished by letters and names; we shall also see presently that they may be distinguished by numbers. They are—

C D E F G A B C

or—Ut, re, mi, fa, sol, la, si, ut.

Such a series of sounds passes under the name of the diatonic scale.

CHAPTER XXXIII.

PHENOMENA OF SOUND.

Notes in unison—Concords and Discords—Octave—Interval of Sounds—Melody—Harmony—The Monochord—Length of Cord and Number of Vibrations required for each Note—Laws of Vibrations in Cords, Rods, Planes—Acoustic Figures on Plates—Vibration of Columns of Air—Interference of Sounds—Whispering Galleries—Echoes—Speaking and Hearing Trumpet.

Two notes are said to be in *unison* when the vibrations which cause them are performed in equal times. If the one makes twice as many vibrations as the other, it is said to be its *octave*, and the *relation* or *interval* there is between two sounds is the proportion between their respective numbers of vibrations.

[When two strings are vibrating together in different times, or not in unison, the ear can distinctly perceive the note of both; but, besides those two separate notes, there will be an impression from the two jointly, very different from that which it receives from either of them separately, and which leads to some curious considerations. This impression is sometimes most agreeable, at others harsh and grating, and according to these sensations the sounds are said to be in accordance or discordance. But the remarkable fact is, that this impression of concord will be experienced whenever the number of vibrations of the individual notes are in some near relation to each other, as 1 to 2, 1 to 3, 2 to 3, &c.; that is, where one string makes two, three, or four vibrations while the other makes one, or accomplishes three while the other accomplishes two or four; and the concord is the more perfect and pleasing the lower the terms of these ratios are. But if, on the contrary, the times of vibration, or number of vibrations in a given time, have not a loud, numerical ratio to each other, but one in which the terms are considerable, as 8 to 15, that is, one string executing fifteen vibrations while the other executes only eight, then there is a discord: the impression on the ear is harsh and disagreeable. The whole harmony consists in following out these laws; any combination of sounds which violate them cannot be agreeable. The pleasure of these harmonious sounds depends, according to Dr. Young, on a love of order and a predilection for a regular recurrence of sensations, primitively implanted in the human mind. Hence,

when two sounds occur together, those proportions are most satisfactory to the ear which exhibit a recurrence of a more or less perfect coincidence at the shortest intervals. This same constitution of the human mind, which fits it for the perception of harmony, appears also to be the cause of the love of rhythm, or of a regular succession of any impressions whatever, at equal intervals of time.—" *The Elements of Physics*," *by Thomas Webster, M.A., page* 208.]

A combination of harmonious sounds is a chord, a succession of harmonious notes a melody, and a succession of chords harmony.

We have remarked in the last chapter that sounds may be expressed by numbers as well as by letters or names, and their relations to one another clearly exhibited. For this purpose we may take the monochord or sonometer, C C′, Fig. 201, an instrument consisting of a wire or catgut stretched over two bridges, F F′, which are fastened on a basis, S S′; one end of the cord passes over a pulley, M, and may be strained to any required degree of weights, P. The length of the string vibrating may be changed by pressing it with the finger upon a movable piece, H, which carries an edge, T, and the case beneath is divided into parts, which exhibit the length of the vibrating part of the wire. The upper part of Fig. 202 shows a horizontal view of the monochord, the lower a lateral view. The instrument here represented has two strings, one of catgut and one of wire.

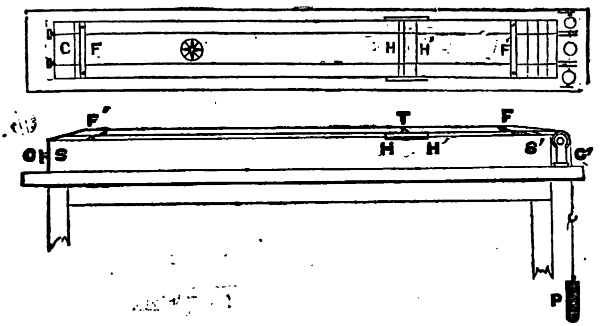


Fig. 201.

Now, it is to be understood that the number of vibrations of such a cord is inversely as its length; that is, if the whole cord makes a given number of vibrations in one second, when you reduce its length to one-half it will make twice as many; if to one-third, thrice as many, &c.

Suppose the cord is stretched so as to give a clear sound, which we may designate as C, and the movable bridge is then advanced so as to obtain successively the other notes of the gamut, D, E, F, G, A, B, C, it will be found that these are given when the lengths of the cord, compared with its original length, are—

Name of note	C	D	E	F	G	A	B	C
Length of cord	1,	$\frac{8}{9}$,	$\frac{4}{5}$,	$\frac{3}{4}$,	$\frac{2}{3}$,	$\frac{3}{5}$,	$\frac{8}{15}$,	$\frac{1}{2}$.

But as the number of vibrations is in the inverse ratio of the lengths of the

vibrating cords, we shall have for the number of vibrations, if we represent by 1 the number that gives C, the following for the other notes :—

Name of note	C	D	E	F	G	A	B	C
Number of vibrations . . .	1,	$\frac{9}{8}$,	$\frac{5}{4}$,	$\frac{4}{3}$,	$\frac{3}{2}$,	$\frac{5}{3}$,	$\frac{15}{8}$,	2.

From C to C is an octave; and from this we gather that, in the octave, the higher note makes twice as many vibrations as the fundamental note, and that between these there are other intervals, which, heard in succession, are harmonious; the eight, therefore, constitute a scale, commonly called the diatonic scale.

Musical instruments are of different kinds, depending on the vibrations of cords, rods, planes, or columns of air.

It has already been stated that the number of vibrations of a cord is inversely as its length; the number also increases as the square root of the force that stretches it; thus, the octave is given by the same string when stretched four times as strongly; the material of the string, whether it be catgut, iron, &c., also affects the note.

In rods, the height of the note is directly as the thickness, and inversely as the square of the length. The quality of the material also, in respect of elasticity, determines the note.

The foregoing observations apply to transverse vibrations of cords and rods; but they may be also made to execute longitudinal and torsion vibrations, the conditions of which are different.

In planes held by one point, and a bow drawn across at another, or struck by a blow, sounds are emitted, and by the aid of sand, nodal lines may be traced. Thus, in Fig. 202, *a* is the point, in each instance, at which the plate is held, and *b* that at which the bow is applied; the sand arranges itself in the dotted lines.

The two large figures are formed by putting together four smaller plates,

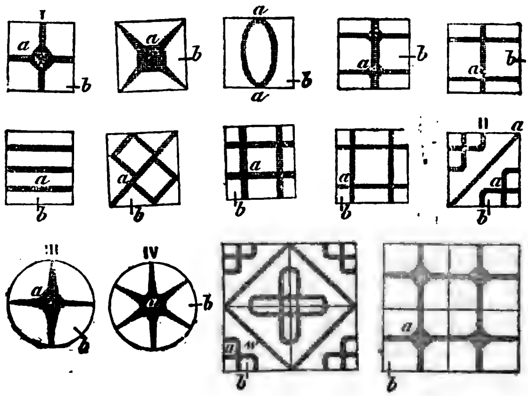


Fig. 202.

in one instance bearing the nodal lines, represented at I, and, in the other, at II. They may, however, be directly generated on one large plate of glass by holding it at *a*, touching it at *w*, and drawing the bow across it at *b*.

Circular plates, *a* in III., may be made to bear a four-rayed star, by holding them in the centre, drawing the bow at any point at *b*, and touching the plate at a point 45° distant from the bow; but if the plate be touched 30°, 60°, or 90° off, it produces a six-rayed star, Fig. IV.

Columns of air may be made to emit sounds by being thrown into oscillation, as in horns, flutes, clarionets, &c. In these, the column of air, included in the tube of the instrument, is made to vibrate longitudinally. The height of the note is inversely proportional to the length of the column, and therefore different notes may be obtained by having apertures, at suitable distances, in the side of the tube, as in the flute.

Two sounds may be so combined together that they shall mutually destroy each other's effect, and silence result. This arises from interference taking place in the aërial waves, the laws of which are those given in Chapter XXXI. The following instances will illustrate these facts:—

When a tuning-fork is made to vibrate, and is turned round upon its axis near the ear, four periods may be discovered during every revolution in which the sound increases or declines. We may produce standing vibrations of the air within a closed tube, by bringing an oscillating body before the open mouth of the tube, so that it may produce such a tone, that the length of the tube is equal to $\frac{1}{4}$, $\frac{3}{4}$, $\frac{5}{4}$, &c., of the wave-length of the tone.

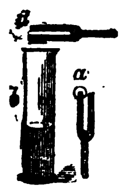


Fig. 203.

If we take two tuning-forks of the same note, *a d*, Fig. 203, and fasten a circle of cardboard, half an inch in diameter, on one of the prongs of each, and make one of the forks a little heavier than the other, by putting on it a drop of wax, and then filling a jar, *b*, to such a height with water, that either of the forks, when held over it, will make it resound, so long as only one is held, there will be a continuous note, without pause or interruption; but if both are held together, there will be periods of silence and periods of sound, according as the longer waves, arising from one of the forks, overtake and interfere with the shorter waves, arising from the other.

[In order to throw the inclosed air into regular vibrations, or to make it resonant with the sounding body, it is not indispensably necessary to bring a sounding body before the opening of a tube. Thus, in organ pipes there is a current of air flowing past the open end of the tube, breaking against the edges, and creating, by its impulses, waves that are reflected on the bottom, and interfere with the newly incident waves. Although these impulses are at first not quite regular, they are soon regulated by the accession of reflected waves, provided the tube sounds well, so that regularly standing waves are formed, by means of which the air in the tube becomes resonant. The notes yielded in this manner by a tube are of the same kind as those which must be given forth by another sounding body brought to the opening of the tube, for the purpose of inducing spontaneous sound in the inclosed air.—*Professor Müller's "Physics and Meteorology," Lecture* XVII.]

Sounds undergo reflection, and may therefore be directed by surfaces of suitable figure. If, in the focus of a concave mirror, a watch be placed, its ticking may be heard at a great distance in the focus of a second mirror, placed so as to receive the sound waves of the first.

On similar principles, also, whispering galleries depend. These are so constructed that a low whisper uttered at one point is reflected to a focus

at another, in which it may be distinctly heard, while it is inaudible in other positions. The dome of St. Paul's Cathedral, in London, is an example.

[The principle of the whispering gallery at St. Paul's may be easily understood by referring to the accompanying diagram. If a sound, such as the tick of a watch, or a low whisper, emanates from the point, A, it may proceed from A to C, and from C to B, by a number of lesser reflections from *d e*, C, *b a* alternately, terminating at B. Thus a sound that could not be conveyed directly from A to B may be heard distinctly by accumulated reflection from several points in the circular surface, A C B.]

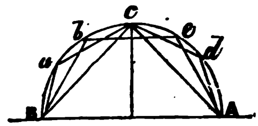


Fig. 204.

Echoes are reflected sounds. Thus, if a person stands in front of a vertical wall, and at a distance from it of about 62½ feet, if he utters a syllable, he will hear a sound which is the echo of it. If there be a series of such vertical obstacles at suitable distances, the same sound may be repeated many successive times. A good ear can distinguish nine distinct sounds in a second; and, as a sound travels 1,120 feet in the same time, for the echo to be clearly distinguished from its original sound, it must travel 125 feet in passing to and from the reflecting surface, that is, the reflector must be at least 62½ feet distant.

Remarkable echoes exist in several places. One near Milan repeats a sound thirty times. The ancients mention one which could repeat the first verse of the Æneid eight times. On the banks of rivers—as, for example, on the Rhine—sounds are often echoed from the rocks, rebounding from side to side.

[Sounds are multiplied by reflection, and the knowledge of this fact is made use of in our large mercantile houses and other establishments, where messages are conveyed from one part of a building to another part, or even from one building to another, by means of tubes. It is probable that this was the means used by Roger Bacon, and others, to make persons unacquainted with acoustics believe that the inanimate figures spoke through their means. One of the most ingenious and celebrated of these scientific deceptions was that exhibited in Paris and London many years ago. It was invented by M. Charles, and styled the "Invisible Girl." Many solutions of this scientific enigma were attempted; but the following may be relied upon, as the editor has many times acted the part of the "Invisible Girl." The apparatus consisted of a wooden frame (B B B, Fig. 205), which was supported upon four pillars (A A A A, Fig. 206). Through one of these pillars

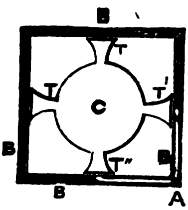


Fig. 205.

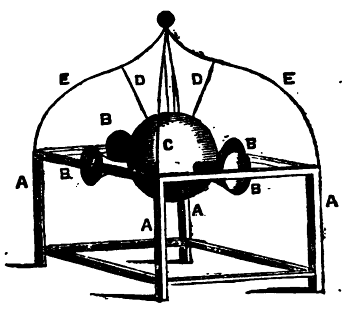


Fig. 206.

a tube passed underneath the floor to an adjoining room, from which the "Invisible Girl" could *see* all that passed, and hear all questions, because the construction of the apparatus favoured it. To each pillar, A, was attached a bent wire, E, which terminated above in a point, and to each of these bent wires was attached a narrow silk ribbon or cord, D D, which supported a hollow copper ball, C, with four trumpets, T′ T″ T T, issuing from it at right angles. The peculiarity consisted in having the copper ball, which was supposed to conceal the "Invisible Girl," suspended by ribbons which were *barely* sufficient to support the weight of the ball. When a question was proposed, the sound passed through the mouth of one of the trumpets to the copper ball, and thence through another of the trumpets (T′ T″, Fig. 205), along canals in the frame (B), to the tube passing through the pillar (A, Fig. 206), to the room in which the person was concealed. This apparatus was exhibited at the Royal Polytechnic Institution many years ago.]

Speaking-trumpets depend on the reflection of sound. The divergence is prevented by the sides of its tube; and if the instrument is of a suitable figure, the rays of sound issue from it, as seen in Fig. 207, in a parallel direction. Its efficiency depends on its length. It is stated that through such an instrument, from eighteen to twenty-four feet long, a man's voice can be heard at a distance of three miles. Under common circumstances, the greatest distances at which sounds have been heard are usually estimated as follow:—The report of a musket, 8,000 paces; the march of a company of soldiers at night, 830 paces; a squadron galloping, 1,080; the voice of a strong man in the open air, 230. But the explosions of the volcano of St. Vincent were heard at Demerara, 345 miles; and at the siege of Antwerp, the cannonading was heard in the mines of Saxony, 370 miles.

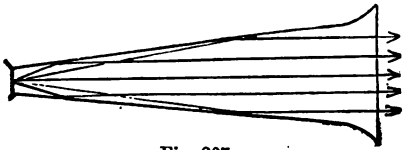


Fig. 207.

The hearing-trumpet is for the purpose of collecting rays of sound by reflection, and transmitting them to the ear.

[The art of ventriloquism appears to depend, in some degree, on the reflection of sounds within the mouth. Professor Dugald Stewart attributed the talent of exciting the perception of articulate sounds, in such a manner as to give them the effect of emission from various distances and directions, wholly to deception and the power of imitation.]

SECOND DIVISION.

SECTION VIII.—PROPERTIES OF LIGHT.—OPTICS.

CHAPTER XXXIV.

PROPERTIES OF LIGHT.

Theories of the Nature of Light—Sources of Light—Phosphorescence—Temperature of a red Heat—Effects of Bodies on Light—Passage in straight Lines—Production of Shadows—Umbra and Penumbra.

HAVING treated of the mechanical properties of gases, liquids, solids, and the laws of motion, we are now led to the consideration of certain agents or forces—light, heat, electricity. These, by many philosophers, are believed to be matter in an imponderable state; they are therefore spoken of as imponderable substances. By others their effects are regarded as arising from motions or modifications impressed on a medium everywhere present, which passes under the name of THE ETHER.

Applying these views to the case of light, two different hypotheses respecting its constitution obtain. The first, which has the designation of the *theory of emission*, regards light as consisting of particles of amazing minuteness, which are projected by the shining body in all directions, and in straight lines. These, impinging eventually on the organ of vision, give rise to the sensation which we speak of as brightness or light. To the other theory the title of *undulatory theory* is given; it supposes that there exists throughout the universe an ethereal medium, in which vibratory movements can arise somewhat analogous to the movements which give birth to sounds in the air; and these passing through the transparent parts of the eye, and falling on the retina, affect it with their pulsations, as waves in the air affect the auditory nerve, but in this case give rise to the sensation of light, as in the other to sound.

There are many different sources of light—some astronomical and some terrestrial. Among the former may be mentioned the sun and the stars—among the latter, the burning of bodies, or combustion, to which we chiefly resort for our artificial lights, as lamps, candles, gas flames. Many bodies are phosphorescent; that is to say, emit light after they have been exposed to the sun or any shining source. Thus oyster-shells, which have been calcined with sulphur, shine in a dark place after they have been exposed to the light, and certain diamonds do the same. So, too, during processes of putrefaction, or slow decay, light is very often emitted, as when wood is mouldering, or meat is becoming putrescent. The source of the luminousness, in these cases, seems to be the same as in ordinary combustions; that

is, the burning away of carbon and hydrogen under the influence of atmospheric air;—but, in certain cases, the functions of life give rise to an abundant emission of light, as in fireflies and glowworms: these continue to shine even under the surface of water, and there is reason to believe that the phenomenon, to a considerable extent, is subject to the volition of the animal.

All solid substances, when they are exposed to a certain degree of heat, become incandescent, or emit light. When first visible in a dark place, this light is of a reddish colour; but as the temperature is carried higher and higher it becomes more brilliant, being next of a yellow, and lastly of a dazzling whiteness. For this reason, we sometimes indicate the temperature of such bodies, in a rough way, by reference to the colour they emit: thus we speak of a red heat, a yellow heat, a white heat. I have recently proved that all solid substances begin to emit light at the same degree of heat, and that this answers to 977° of Fahrenheit's thermometer; moreover, as the temperature rises, the brilliancy of the light rapidly increases, so that at a temperature of 2600° it is almost forty times as intense as at 1900°. At these high temperatures an elevation of a few degrees makes a prodigious difference in the brilliancy. Gases require to be brought to a far higher temperature than solids before they begin to emit light.

Non-luminous bodies become visible by reflecting the light which falls on them. In their general relations, such bodies may be spoken of as transparent and opaque. By the former we mean those which, like glass, afford a more or less ready passage to the light through them; by the latter such as refuse it a passage. But transparency and opacity are never absolute—they are only relative. The purest glass extinguishes a certain amount of the rays which fall on it, and the metals which are commonly looked upon as being perfectly opaque allow light to pass through them, provided they are thin enough. Thus gold leaf spread upon glass transmits a greenish-coloured light.

The rays of light, from whatever source they may come, move forward in straight lines, continuing their course until they are diverted from it by the interposition of some obstacle, or the agency of some force. That this rectilinear path is followed may be proved by a variety of facts. Thus, if we intervene an opaque body between any object and the eye, the moment the edge of that body comes to the line which connects the object and the eye, the object is cut off from our view. In a room into which a sunbeam is admitted through a crevice, the path which the light takes, as is marked out by the motes that float in the air, is a straight line.

By a ray of light we mean a straight line drawn from the luminous body, marking out the path along which the shining particles pass.

A shining body is said to radiate its light, because it projects its luminous particles in straight lines, like radii, in every direction, and these falling on opaque bodies, and being intercepted by them, give rise to the production of shadows.

If the light is emitted by a single luminous point, the boundary of the shadow can be obtained by drawing straight lines from the luminous point to every point on the edge of the body, and producing them. Thus, let *a*, Fig. 208, be the luminous point, *b c* the opaque body; by drawing the lines, *a b*, *a c*, and producing them to *d* and *e*, the boundary and figure of the shadow may be exhibited.

But if the luminous body, as in most instances is the case, possesses a

sensible magnitude; if it is, for example, the sun or a flame, an opaque body will cast two shadows, which pass respectively under the names of the *umbra* and *penumbra*—the former being dark, and the latter partially illuminated. This may be illustrated by Fig. 209, in which *a b* is the flame of a candle, or any other luminous source, having a sensible magnitude, *c d* the opaque body. Now the straight lines, *a c f*, *a d h*, drawn from the top of the flame to the edges of the opaque body and produced, give the shadow for that point of the flame; and the lines *b c e*, *b d g*, drawn in like manner from the bottom of the flame, give the shadow for that point. But we see that the space between *g* and *h*, which belongs to the shadow for the top of the flame, is not perfectly dark, because it is so situated as to be partially illuminated by the bottom of the flame—and a similar remark may be made as respects the space, *f e*, which receives light from the top of the flame. But the remaining space, *f g*, receives no light whatever—it is totally dark—and we therefore call it the *umbra*, while the partially illuminated regions, *f e* and *g h*, are the *penumbra*.

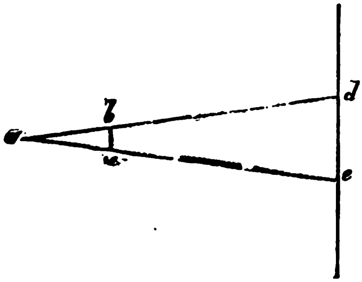


Fig: 208.

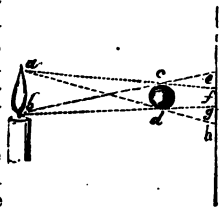


Fig. 209.

CHAPTER XXXV.

OF THE MEASURES OF THE INTENSITY AND VELOCITY OF LIGHT.

Conditions of the Intensity of Light—Of Photometric Methods—Rumford's Method by Shadows—Ritchie's Photometer—Difficulties in Coloured Lights—Masson's Method—Velocity of Light determined by the Eclipse of Jupiter's Satellites—The same by the Aberration of the Fixed Stars.

By Photometry* we mean the measurement of the brilliancy of light—an operation which can be conducted in many different ways.

It is to be understood that the illuminating power of a shining body depends on several circumstances. First, upon its distance—for near at hand the effect is much greater than far off—the law for the intensity of light in this respect being, that the brilliancy of the light is inversely as the square of the distance. A candle two feet off gives only one-fourth of the light that it does at one foot; at three feet it gives only one-ninth, &c. Secondly, it depends on the absolute intensity of the luminous surface: thus we have seen that a solid, at different degrees of heat, emits very different amounts of light; and in the same way the flame of burning hy-

* This term is derived from the two Greek words, *phose* (φως), light, and *metron* (μετρον), a measure.

drogen is almost invisible, and that of spirits of wine is very dull when compared with an ordinary lamp. Thirdly, it depends on the area or surface the shining body exposes, the brightness being greater according as that surface is greater. Fourthly, in the absorption which the light suffers in passing the medium through which it has to traverse—for even the most transparent obstructs it to a certain extent. And lastly, on the angle at which the rays strike the surface they illuminate, being most effective when they fall perpendicularly, and less in proportion as their obliquity increases.

The first and last of the conditions here mentioned, as controlling the intensity of light—the effect of distance and of obliquity—may be illustrated as follows :—

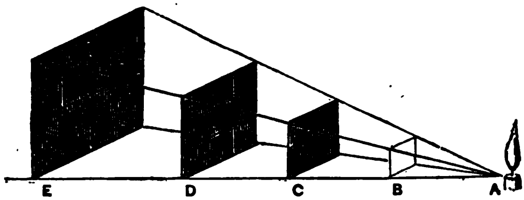


Fig. 210.

1st. That the intensity of light is inversely as the squares of the distance. Let B, Fig. 210, be an aperture in a piece of paper, through which rays coming from a small illuminated point, A, pass; let these rays be received on a second piece of paper, C, placed twice as far from A as is B, it will be found that they illuminate a surface which is twice as long and twice as broad as A, and therefore contains four times the area. If the paper be placed at D, three times as far from A as is B, the illuminated space will be three times as long and three times as broad as A, and contain nine times the surface. If it be at E, which is four times the distance, the surface will be sixteen times as great. All this arises from the rectilinear paths which the diverging rays take, and therefore a surface illuminated by a given light will receive, at distances represented by the numbers 1, 2, 3, 4, &c., quantities of light represented by the numbers 1, $\frac{1}{4}$, $\frac{1}{9}$, $\frac{1}{16}$, &c., which latter are the inverse squares of the former numbers.

2nd. That the intensity of light is dependent on the angle at which the rays strike the receiving surface, being most effective when they fall perpendicularly, and less in proportion as the obliquity increases. Let there be two surfaces, D C and E C, Fig. 211, on which a beam of light, A B, falls on the former perpendicularly, and on the latter obliquely—the latter surface, in proportion to its obliquity, must have a larger area to receive *all* the rays which fall on D C. A given quantity of light,

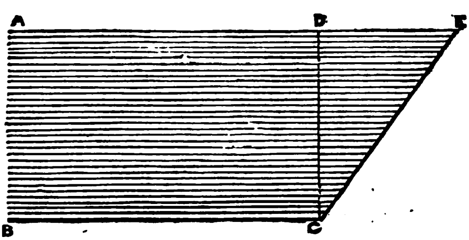


Fig. 211.

therefore, is diffused over a greater surface when it is received obliquely, and its effect is correspondingly less.

To compare different lights with one another, Count Rumford invented a process which goes under the name of the method of shadows. The principle is very simple. Of two lights, that which is the most brilliant will cast the deepest shadow, and with any light the shadow which is cast becomes less dark as the light is more distant. If, therefore, we wish to examine experimentally the brilliancy of two lights on Rumford's method, we take a screen of white paper, and setting in front of it an opaque rod, we place the lights in such a position that the two shadows arising shall be close together, side by side. Now the eye can, without any difficulty, determine which of the two is darkest; and by removing the light, which has cast it to a greater distance, we can, by a few trials, bring the two shadows to precisely the same degree of depth. Now measure the distances of the two lights from the screen, and the illuminating powers are as the squares of those distances.

Ritchie's photometer is an instrument for obtaining the same result; not, however, by the contrast of shadows, but by the equal illumination of surfaces. It consists of a box, *a b*, Fig. 212, six or eight inches long, and one broad and deep, in the middle of which a wedge of wood, *f e g*, with its angle, *e*, upward, is placed. This wedge is covered over with clean white paper, neatly doubled to a sharp line at *e*. In the top of the box there is a conical tube, with an aperture, *d*, at its upper end, to which the eye is applied, and the whole may be raised to any suitable height by means of the stand, *c*. On looking down through *d*, having previously placed the two lights, *m n*, the intensity of which we desire to determine on opposite sides of the box, they illuminate the paper surfaces exposed to them, *e f* to *m*, and *e g* to *n*, and the eye, at *d*, sees both those surfaces at once. By changing the position of the lights, we eventually make them illuminate the surfaces equally, and then measuring their distances from *e*, their illuminating powers are as the squares of those distances.

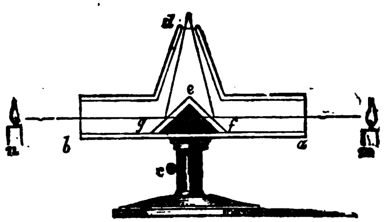


Fig. 212.

It is not possible to apply either of these methods in a satisfactory manner, where, as is unfortunately often the case, the lights to be examined differ in colour. The eye can form no judgment whatever of the relation of brightness of two surfaces when they are of different colours; and a very slight amount of tint completely destroys the accuracy of these processes. To some extent, in Ritchie's instrument, this may be avoided by placing a coloured glass at the aperture, *d*.

A third photometric method has recently been introduced; it has great advantages over either of the foregoing; and difference of colour, which in them is so serious an obstacle, serves in it actually to increase the accuracy of the result. The principle on which it is founded is as follows: If we take two lights, and cause one of them to throw the shadow of an opaque body upon a white screen, there is a certain distance to which, if we bring

the second light, its rays, illuminating the screen, will totally obliterate all traces of the shadow. This disappearance of the shadow can be judged of with great accuracy by the eye. It has been found that eyes of average sensitiveness fail to distinguish the effect of a light when it is in presence of another sixty-four times as intense. The precise number varies somewhat with different eyes; but to the same eye it is always the same. If there be any doubt as to the perfect disappearance of the shadow, the receiving screen may be agitated or moved a little. This brings the shadow, to a certain extent, into view again. Its place can then be traced, and, on ceasing the motion, the disappearance verified.

When, therefore, we desire to discover the relative intensities of light, we have merely to inquire at what distance they effect the total obliteration of a shadow, and their intensities are as the squares of those distances. This method has been employed for the determination of the quantities of light emitted by a solid at different temperatures, and found very exact.

Light does not pass instantaneously from one point to another, but with a measurable velocity. The ancients believed that its transmission was instantaneous, illustrating it by the example of a stick, which, when pushed at one end, simultaneously moves at the other. They did not know that even their illustration was false; for a certain time elapses before the further end of the stick moves; and, in reality, a longer time than light would require to pass over a distance equal to the length of the stick. But, in 1676, a Danish astronomer, Roemer, found, from observations on the eclipses of Jupiter's satellites, that light moves at the rate of about 192,000 miles in one second.

This singular observation may be explained as follows: Let S, Fig. 213, be the sun, E the earth, moving in the orbit, E E′, as indicated by the arrows; let J be Jupiter, and T his first satellite, moving in its orbit round him. It takes the satellite 42 hours, 28 minutes, 35 seconds, to pass from T to T′—that is to say, through the planet's shadow. But, during this period of time, the earth moves in her orbit, from E to E′, a space of 2,880,000 miles. Now, it is found, under these circumstances, that the emersion of the satellite is 15 seconds later than it should have been. And it is clear that this is owing to the fact that the light requires 15 seconds to pass from E to E′, and overtake the earth. Its velocity, therefore, in one second, must be 192,000 miles.

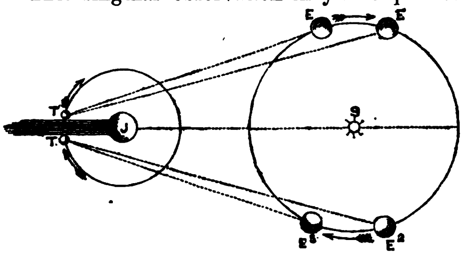


Fig. 213.

This beautiful deduction was corroborated by Dr. Bradley, in 1725, upon totally different principles, involving what is termed the aberration of the stars. The principle, which is somewhat difficult to explain, is clearly illustrated by Eisenlohr as follows: Let M N represent a ship, whose side is aimed at point-blank by a cannon at *a*. Now, if the vessel were at rest, a ball discharged in this manner would pass through the points *b* and *c*, so that the three points, *a*, *b*, and *c*, would all be in the same straight

line. But if the vessel itself move from M towards N, then the ball which entered at *b* would not come out at the opposite point, *c*, but at some other point, *d*, as much nearer to the stern as is equal to the distance gone over by the vessel, from M to N, during the time of passage of the ball through her. The lines *b c* and *b d*, therefore, form an angle at *b*, whose magnitude depends on the position of *b c* and *b d*. The greater the velocity of the ball, as compared with the ship, the less the angle. Next, for the ship substitute in your mind the earth, and for the cannon any of the fixed stars; let the velocity, *b c*, of the cannon-ball now stand for that of light, and let *d c* be the velocity of the earth in her orbit. The angle, *d b c*, is called the angle of aberration. It amounts to $20\frac{1}{4}$ seconds for all the stars; for they all exhibit the same alteration in their apparent position, being more backward than they really are in the direction of the earth's annual motion, as Bradley discovered. By a simple trigonometrical calculation, it appears from these facts that the velocity of light is 195,000 miles per second, a result nearly coinciding with the former.

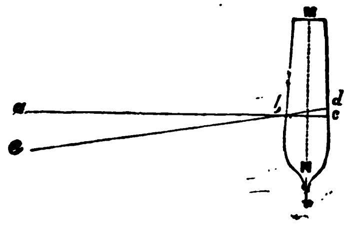


Fig. 214.

CHAPTER XXXVI.

REFLECTION OF LIGHT.

Different kinds of Mirrors—General Law of Reflection—Case of Parallel, Converging, and Diverging Rays on Plane Mirrors—The Kaleidoscope—Properties of Spherical Concave Mirrors—Properties of Spherical Convex Mirrors—Spherical Aberration—Mirrors of other Forms—Cylindrical Mirrors.

WHEN a ray of light falls upon a surface, it may be reflected, or transmitted, or absorbed.

We therefore proceed to the study of these three incidents which may happen to light, commencing with reflection.

Reflecting surfaces in optics are called mirrors; they are of various kinds, as of polished metal or glass. They differ also as respects the figure of their surfaces, being plane, convex, or concave; and again they are divided into such as are spherical, parabolic, elliptical, &c.

The general law which is at the foundation of this part of optics—the law of reflection—is as follows:—

The angle of reflection is equal to the angle of incidence; the reflected ray is in the opposite side of the perpendicular; and the perpendicular, the incident, and the reflected rays are all in the same plane.

Thus let *i*, Fig. 215, be the reflecting surface; *b i* a perpendicular to it

at any point, *n i* a ray incident on the same point; the path of the reflected ray under the foregoing law will be *i d*: such that it is on the opposite side of the perpendicular to the incident ray, that *n i*, *i p*, and *i d*, are all in the same plane, and that the angle of incidence, *n i p*, is equal to the angle of reflection, *i p d*.

Reflection from mirror surfaces may be studied under three divisions—reflection frm plane, from concave, and from convex mirrors.

When parallel rays fall on a plane mirror, they will be reflected parallel, and divergent and convergent rays will respectively diverge and converge at angles equal to their angles of incidence.

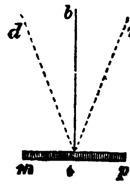


Fig. 215.

When rays diverging from a point fall on a mirror, they are reflected from it in such a manner as though they proceeded from a point as far behind it as it is in reality before it. This principle has already been explained in Chapter XXXI. It is illustrated in Fig. 216. Thus, if from the point *a* two rays, *a b*, *a c*, diverge, they will, under the general law, be respectively reflected along *b d*, *c e*; and if these be produced they will intersect at *a'*, as far behind the mirror as *a* is before it. The point *a'* is called the virtual focus.

From this it appears that any object seen in a plane mirror appears to be as far behind it as it is in reality before it.

If an object is placed between two parallel plane mirrors, each will produce a reflected image, and will also repeat the one reflected by the other. The consequence is, therefore, that there is an indefinite number of images produced, and in reality the number would be infinite, were the light not gradually enfeebled by loss at each successive reflection.

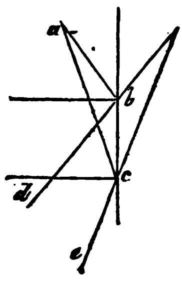


Fig. 216.

The kaleidoscope is a tube containing two plane mirrors, which run through it lengthwise, and are generally inclined at an angle of 60°. At one end of the tube is an arrangement by which pieces of coloured glass or other objects may be held, and at the other there is a cap with a small aperture. On placing the eye at this aperture the objects are reflected, and form a beautiful hexagonal combination; their position and appearance may be varied by turning the tube round on its axis.

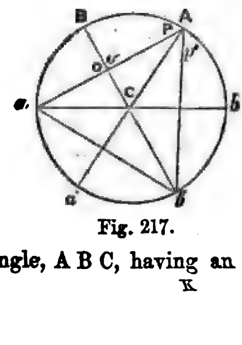


Fig. 217.

The principle upon which the kaleidoscope is constructed is the multiplication of the reflection of an object caused by placing it between two mirrors inclined towards each other at any angle, but usually at 60°. This instrument was invented or revived by Sir David Brewster, who took out a patent for it in 1817. The accompanying figure represents two mirrors inclined towards each other at an angle, A B C, having an ob-

ject, O P, placed between them. The consequence of this arrangement is, that several images will be observed arranged within the circumference of a circle. Thus we observe in the diagram that the image, O P, in the mirror, A C, is *p o*, while its image in B C is *o p*; and therefore the reflection of *p o* in B C will be *o p*, while the image of *o p* in A C will be *p o*. It therefore appears that *p o* is the image of both, P O, in the mirror, *b* C, and of *o p* in the mirror, *a* C, one of the images covering the other, if the angle B C A be *b* (or the sixth part of a circle), as in the diagram. If the angle be greater or less, the image, *p* O, will be twofold.

Concave and convex mirrors are commonly ground to a spherical figure, though other figures, such as ellipsoids, paraboloids, &c., are occasionally used for special purposes. It is the properties of spherical concaves that we shall first describe.

The general action of a spherical mirror may be understood by regarding it as made up of a number of small plane mirrors, as A, B, C, D, E, F, G, Fig. 218. On such a combination of small mirrors let rays emanating from R impinge. The different degrees of obliquity under which they fall upon the mirrors cause them to follow new paths after reflection, so that they converge to the point S as to a focus.

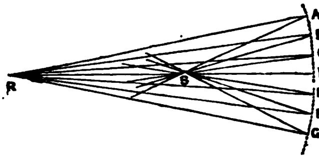


Fig. 218.

The problem of determining the path of a ray after it has been reflected is solved by first drawing a perpendicular to the surface at the point of impact, and then drawing a line on the opposite side of this perpendicular, making with it an angle equal to that of the angle of incidence of the incident ray. Thus, let *r s*, Fig. 219, be an incident ray falling on any reflecting surface at *s*. To find the path it will take after reflection, we first draw *s c*, a perpendicular to the surface at the point of impact, *s*; and then draw the line *s f* on the opposite side of the perpendicular *c s*, such that the angle *c s f* is equal to the angle *c s r*. This is nothing but an application of the general law of reflection, that the angles of incidence and reflection are equal to one another, and are on opposite sides of the perpendicular.

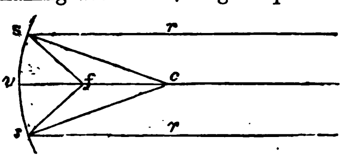


Fig. 219.

When rays of light diverge from the centre of a spherical concave mirror after reflection they converge back to the same point; for, from the nature of such a surface, lines drawn from its centre are perpendicular to the point to which they are drawn. Every ray, therefore, impinges perpendicularly upon the surface, and returns to the centre again.

When parallel rays of light fall on the surface of a spherical mirror, the aperture or diameter of which is not very large, they are reflected to a point half way between the surface and centre of the mirror. Thus, let *r s r′ s′* be parallel rays falling on the mirror, *s s′*, the aperture, *s s′*, of which is only a few degrees, these rays, after reflection, will be found converging to the point *f*, which is called the *principal focus*, half way between the vertex of the mirror, *v*, and its centre, *c*; for if we draw the radii, *c s c′ s′*, these lines are perpendiculars to the mirror at the points on which they

fall; then make the angles $c\ s\ f$ equal $c\ s\ r$, and $c'\ s\ f$ equal $c\ s'\ r'$, and it is easy to prove that the point f is midway between v and c.

But if the aperture, $s\ s'$, of the mirror exceeds a few degrees, it may be proved geometrically that the rays no longer converge to the focus, f; but, as the aperture increases, they are found nearer and nearer to the vertex, v, until finally, were it not for the opacity of the mirror, they would fall at the back of it. As this deviation is dependent on the spherical figure of the mirror, it is termed aberration of sphericity.

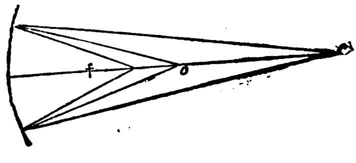


Fig. 220.

Conversely, if diverging rays issue, from a lucid point, f, Fig. 219, half way between the vertex and centre of a spherical mirror of limited aperture, they will be reflected in parallel lines.

Rays coming from any point, r, Fig. 220, at a finite distance beyond the centre of the mirror, will be reflected so as to fall between the focus, f, and the centre, c.

Rays coming from a point, r, Fig. 221, between the focus, f, and the vertex, v, will diverge after reflection. Under such circumstances a virtual focus, f, exists at the back of the mirror.

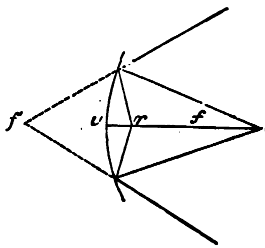


Fig. 221.

Concave mirrors give rise to the formation of images in their foci. This fact may be shown experimentally by placing a candle at a certain distance in front of such a mirror, and a small screen of paper at the focus. On this paper will be seen an image of the flame, beautifully clear and distinct, but inverted. The relative size and position of this image varies according to the distance of the object from the vertex of the mirror.

The second variety of curved mirrors is the convex; their chief properties are as follow:—

When parallel rays fall on the surface of a convex mirror, they become divergent after reflection; for let $s\ s'$ be such a mirror, and $r\ s\ r'\ s'$ rays parallel to its axis falling on it; let c be the centre of the mirror, and draw $c\ s\ c\ s'$, which will be respectively perpendicular to the mirror at the points s and s'; then for the reflected rays, make the angle, $t\ s\ p$, equal to $p\ s\ r$, and the angle, $t'\ s'\ p'$, equal to $p'\ s'\ r'$; it may then be demonstrated, that not only do these reflected rays diverge, but if they be produced through the mirror till they intersect, they will give a virtual focus at f, half-way between the vertex

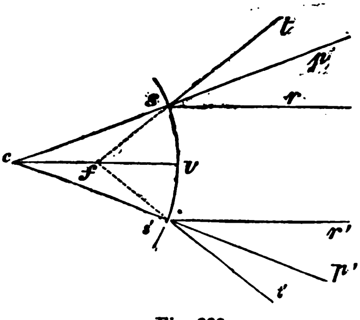


Fig. 222.

of the mirror, r, and its centre, c, so long as the mirror is of a limited aperture.

In a similar manner it may be proved that diverging rays falling on a convex mirror become more divergent.

To avoid the effect of spherical aberration, it has been proposed to give to mirrors other forms than the spherical. Some are ground to a paraboloidal, and others to an ellipsoidal figure. Of the properties of such surfaces I have already spoken, under the theory of undulations, in Chapter XXXI.; and the effects remain the same, whether we consider light as consisting of innumerable small particles shot forth with great velocity, or of undulations arising in an elastic ether. In both cases parallel rays, falling on a paraboloidal mirror, are accurately converged to the focus, whatever the aperture of the mirror may be; and in ellipsoidal ones, rays diverging from one of the foci are collected together in the other. Occasionally, for the purposes of amusement, mirrors are ground to cylindrical or conical figures; they distort the appearance of objects presented to them, or reflect, in proper proportions, the images of distorted or ludicrous paintings.

CHAPTER XXXVII.

REFRACTION OF LIGHT.

Refractive Action described—Law of the Sines.—Relation of the Refractive Power with other Qualities—Total Reflection—Rays on plane Surfaces—The Prism—Action of the Prism on a Ray—The Multiplying-glass.

WHEN a ray of light passes out of one medium into another of a different density, its rectilinear progress is disturbed, and it bends into a new path, This phenomenon is designated the refraction of light.

Thus, if a sunbeam, entering through a small hole in the shutter of a dark room, falls on the surface of some water contained in a vessel, the beam, instead of passing on in a straight line, as it would have done had the water not intervened, is bent or broken at the point of incidence, and moves in the new direction.

In the same way, also, if a coin or any other object, O, Fig. 223, be placed at the bottom of an empty bowl, A B C D, and the eye at E so situated that it cannot perceive the coin, the edge of the vessel intervening, if we pour in water the object comes into view; and the cause of this is the same as in the former illustration: for while the vessel is empty the ray is obstructed by the edge of the bowl, as at O G E, but when water is poured into the height F G, refraction at the point L, from the perpendicular, P Q, ensues; and now the ray takes the course O L E, and entering the eye at E, the

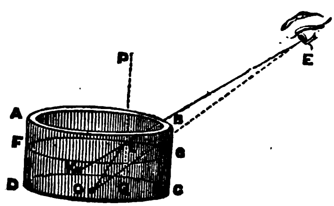


Fig. 223.

object appears at K, in the line E L K. For the same reason oars or straight sticks immersed in water look broken, and the bottom of a stream seems at a much less depth than what it actually is.

The same result ensues under the circumstances represented in Fig 224, in which E represents a candle, the rays of which fall on a rectangular box, A B C D, under such circumstances as to cast the shadow of the side A C so as to fall at D. If the box be now filled with water, everything remaining as before, the shadow will leave the point D, and go to *d*, the rays undergoing refraction as they enter the liquid; and if the eye could be placed at *d*, it would see the candle at *e*, in the direction of *d* A produced.

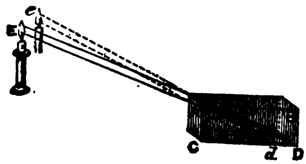


Fig. 224.

Let N O, Fig 225, be a refracting surface, and C the point of incidence of a ray, B C, C E the course of the refracted ray, and C K the course the ray would have taken had not refraction ensued. With the point of incidence, C, as a centre, describe a circle, N M O G, and from A and R draw the lines A D, R H at right angles to the perpendicular M G to the point C. Then A C M will be the angle of incidence, R C G the angle of refraction; A D is the sine of the angle of incidence, and H R the sine of the angle of refraction. Now in every medium these lines have a fixed relation to one another, and the general law of refraction is as follows:—

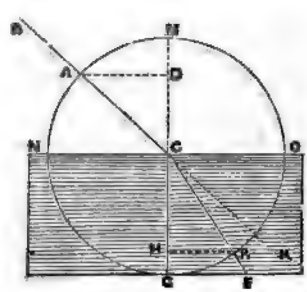


Fig. 225.

In each medium the sine of the angle of incidence is in a constant ratio to the sine of the angle of refraction; the incident, the perpendicular, and the refracted ray are all in the same plane, which is always at right angles to the plane of the refracting medium.

To a beginner, this law of the constancy of sines may be explained as follows:—Let C D, Fig. 226, be a ray falling on a medium, A B, in the point D, where it undergoes refraction, and takes the direction D E. Its sine of incidence, as just explained, is C *g*, and its sine of refraction E *e*; and let us suppose that the medium is of such a nature that the sine of refraction is one-half the sine of incidence—that is, E *e*, is half C *g*. Moreover, let there be a second ray, H D, incident also at the point D, and refracted along D F; H *h* will be its sine of incidence, and F *f* its sine of refraction; and by the law F *f* will be exactly one-half H *h*. The proportion or relation between these sines differs when different media are used, but for

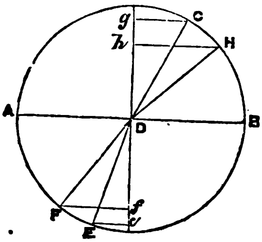


Fig. 226.

the same medium it is always the same. Thus, in the case of water, the proportion is as 1·366 to 1; for flint-glass, 1·584 to 1; for diamond, 2·487 to 1. These numbers are obtained by experiment. They are called the indices of refraction of bodies, and tables of the more common substances are given in the larger works on optics.

No general law has as yet been discovered which would enable us to predict the refractive power of bodies from any of their other qualities; but it has been noticed that inflammable bodies are commonly more powerful than incombustible ones, and those that are dense are more energetic than those that are rare.

When a ray of light passes out of a rare into a dense medium, it is refracted *toward* the perpendicular. Fig. 224 is an illustration—the rays passing from air into water. But when a ray passes from a dense into a rarer medium, it is refracted *from* the perpendicular. Fig 223 is an example—the rays passing from water into air.

In every case, when a ray falls on the surface of any medium whatever, it is only a portion which is transmitted, a portion being always reflected. If in a dark room we receive a sunbeam on the surface of some water, this division into a reflected and a refracted ray is very evident; and when a ray is about to pass out of a highly refractive medium into one that is less so, making the angle of incidence so large that the angle of refraction is equal to or exceeds 90°, total reflection ensues. This may be readily shown by allowing the rays from a candle, *f*, or any other object, to fall on the second face, *b c*, of a glass prism, *a b c*, Fig. 227; the eye placed at *d* will receive the reflected ray, *d e*, and it will be perceived that the face, *b c*, of the glass, when exposed to the daylight, appears as though it were silvered, reflecting perfectly all objects exposed to its front, *a c*.

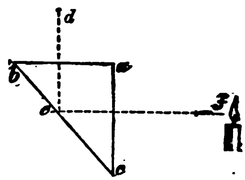


Fig. 227.

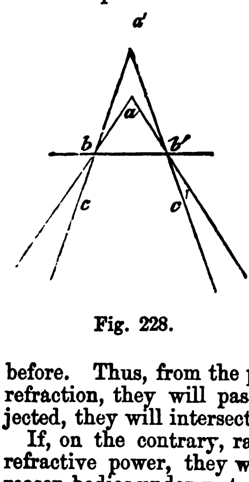


Fig. 228.

As with the reflection of light, so with refraction—it is to be considered as taking place on plane, convex, and concave surfaces.

When parallel rays fall upon a plane refracting surface they continue parallel after refraction. This must necessarily be the case, on account of the uniform action of the medium.

If divergent rays fall upon a plane of greater refractive power than the medium through which they have come, they will be less divergent than before. Thus, from the point *a* let the rays *a b*, *a b'* diverge; after suffering refraction, they will pass in the paths *b c*, *b' c'*, and if these lines be projected, they will intersect at *a'*, but *a' b*, *a' b'* are less divergent than *a b*, *a b'*.

If, on the contrary, rays pass from a medium of greater to one of less refractive power, they will be more divergent after refraction. For this reason bodies under water appear nearer the surface than they actually are.

When parallel rays of light pass through a medium bounded by planes

that are parallel, as through a plate of glass, they will continue still parallel to one another, and to their original direction, after refraction. For this reason, therefore, we see through such plates of glass objects in their natural positions and relation.

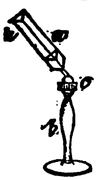


Fig. 229.

The optical prism is a transparent medium, having plane surfaces inclined to one another. It is usually a wedge-shaped piece of glass, *a a*, Fig. 229, which can be turned into any suitable position, on a ball and socket-joint, *c*, and is supported on a stand, *b*. As this instrument is of great use in optical researches, we shall describe the path of a ray of light through it more minutely.

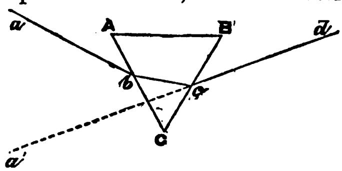


Fig. 230.

Let, therefore, A B C, Fig. 230, be such a glass prism seen endwise, and let *a b* be a ray of light incident at *b*. As this ray is passing from a rarer to a denser medium it is refracted toward the perpendicular to an extent dependent on the refractive power of the glass of which the prism is composed, and therefore pursues a new path, *b c*, through the glass; at *c* it again undergoes refraction, and now passing from a denser to a rarer medium, takes a new course, *c d*. To an eye placed at *d*, and looking through the prism, an object, *a*, seems though it were at *a'*, in the straight line, *d c* continued. Through this instrument, therefore, the position of objects is changed, the refracted ray, *c d*, proceeding towards the back, A B, of the prism.

But the prism in actual practice gives rise to far more complicated and interesting effects, to be described hereafter, when we come to speak of the colours of light.

The multiplying-glass is a transparent body, having several inclined faces. Its construction and action are represented at Fig. 231. Let A B be a plane face, C D also plane and parallel to it, but A C and D B inclined. Now let rays come from any object, *a*, those, *a b*, which fall perpendicularly on the two faces will pass without suffering refraction; but those, *a c*, *a d*, which fall on the inclined faces, will be refracted into new paths, *c f*, *d f*, these portions acting like the prism heretofore described. Consequently an eye placed at *f* will see three images of the object in the direction of the lines along which the rays have come—that is, at *a'*, *a*, *a''*. Hence the term *multiplying-glass*, because it gives as many figures of an object as it has inclined surfaces.

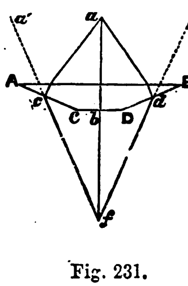


Fig. 231.

CHAPTER XXXVIII.

THE ACTION OF LENSES.

Different Forms of Lenses—General Properties of Convex Lenses—General Properties of Concave Lenses—Analogy between Mirrors and Lenses—Production of Images by Lenses—Size and Distance of Images—Visual Angle—Magnifying Effects—Burning Lenses.

TRANSPARENT media having curved surfaces are called lenses. They are of seven different kinds, as represented in Fig. 232. The plano-convex lens, 3, has one surface plane and the other convex; the plano-concave, 5, has one surface plane and the other concave; 2 is the double convex; 4 the double concave; 7 the meniscus; 1 the sphere, or globe; and 6 the concavo-convex.

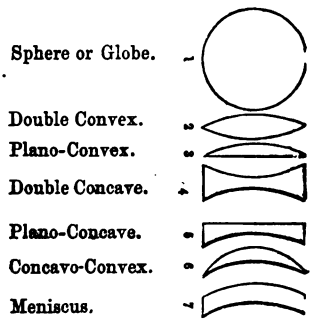


Fig. 232.

For optical uses lenses are commonly made of glass, but for certain purposes other substances are employed. For example, rock crystal is often used for making spectacle lenses; it is a hard substance, and is not, therefore, so liable to be scratched or injured as glass.

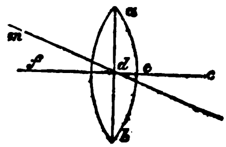


Fig. 233.

In a lens the point *c* is called the *geometrical centre*, for all lenses are ground to spherical surfaces, and *c* is the centre of their curvature; the aperture of the lens is *a b*, and *d* is its *optical centre; f e* is the axis, and any ray, *m n*, which passes through the optical centre, is called a principal ray.

The general action of lenses of all kinds may be understood after what has been said in relation to the prism, of which it was remarked that the refracted ray is bent toward the back. Thus, if we have two prisms, *a c e*, *b c e*, placed back to back, and allow parallel rays of light, *m n*, to fall upon them, these rays, after refraction, being bent from their parallel path toward the back of each prism, will intersect each other in some point, as *f*. Now, there is obviously a strong analogy between the figure of the double convex lens, and that of these two prisms; indeed, the former might be regarded as a series of prisms with curved surfaces, and from such consideration it is clear, that when parallel rays fall on a convex lens, they will converge to a focal point.

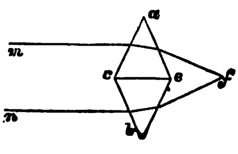


Fig. 234.

Again, let us suppose that a pair of prisms be placed edge to edge, as shown in Fig. 235, and that parallel rays, *m n*, are incident upon them. These rays undergo refraction, as before, toward the back of their respective prisms, *b c*, *d e*, and therefore emerge divergent, as at *f* and *g*. Now, there

is an analogy between such a combination of prisms and a concave lens, and we therefore see that the general action of such a lens upon parallel rays is to make them divergent.

By the aid of the law of refraction it may be proved that lenses possess the following properties:—

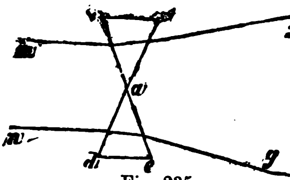


Fig. 235.

Every principal ray which falls upon a convex lens of limited thickness is transmitted without change of direction.

Rays parallel to the axis of a double equi-convex glass lens are brought to a focus at a distance from the optical centre equal to the radius of curvature of the lens. But if it be a plano-convex glass, the focal distance is twice as great. The focus for parallel rays is called the principal focus.

Rays diverging from the principal focus of a convex lens after refraction become parallel.

Rays diverging from a point in the axis more distant than the principal focus converge after refraction, their point of convergence being nearer the lens as the point from which they radiated was more distant.

Rays coming from a point in the axis nearer than the principal focus diverge after refraction.

With respect to concave lenses, the chief properties may be described as follow:—

Every principal ray passes without change of direction.

Rays parallel to the axis are made divergent. Thus *m n*, Fig. 236, being parallel rays falling on the double concave, *a b*, diverge after refraction in the directions *g d*; and if they be produced, give rise to a virtual or imaginary focus at *f*.

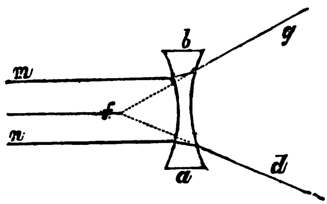


Fig. 236.

By concave lenses diverging rays are made still more divergent.

When the effects of lenses are compared with those of mirrors, it will be found that there is an analogy in the action of concave mirrors and convex lenses, and of convex mirrors and concave lenses.

It has already been remarked that concave mirrors give images of external objects in their focus. The same holds good for convex lenses. Thus, if we take a convex lens, and place behind it, at the proper distance, a paper screen, we shall find upon that screen beautiful images of all the objects in front of the lens in an inverted position. The manner in which they form may be understood from Fig. 237. Where L′ L is a double convex lens, M N any object, as an arrow, in front of it, the lens will give an inverted image, *n m*, of the object at a proper distance behind. From the point M all the rays, as

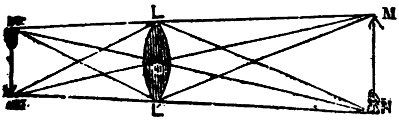


Fig. 237.

M L, M C, M L′, after refraction, will converge to a focus, *m*; and from the point N all rays, as N L, N C, N L′, will likewise converge to a focus, *n*; and so, for every intermediate point between M and N, intermediate foci will form between *m* and *n*, and therefore conjointly give rise to an inverted image.

The images thus given by lenses or mirrors may be made visible by being received on white screens, or on smoke rising from a combustible body, or directly by the eye placed in a proper position to receive the rays. They then appear as if suspended in the air, and are spoken of as aërial images.

The distance of such images from a lens, and also their magnitude, vary with circumstances.

If the object be very remote, it gives a minute image in the focus of the lens; as it is brought nearer, the image recedes further, and becomes larger; when it is at a distance equal to twice the focal distance, the image is equidistant from the lens on the opposite side, and is of the same size as the object. As the object approaches still nearer, the image recedes, and now becomes larger than the object. When it reaches the focus, the image is at an infinite distance, the refracted rays being parallel to one another. And, lastly, when the object comes between the focus and the surface of the lens, an erect and magnified image of the object will appear on the same side of the lens as the object itself. Hence convex glasses are called magnifying-glasses.*

From these considerations it therefore appears that the magnifying power of lenses is not, as is often popularly supposed, due to the peculiar nature of the glass of which they are made, but to the figure of their surfaces. The dimensions of all objects depend on the angles under which they are seen. A coin at a distance of 100 yards appears of a very small size; but as it is brought nearer the eye, its size increases, and when only a few inches off, it can obstruct the view of large objects. Thus, if A represents its size at a remote distance, the angle D E F, or the visual angle, is the angle under which it is seen; when brought nearer, at B, the angle is G E H; and at C increases to I E K. In all cases the apparent size of an object increases as the visual angle increases, and all objects become smaller as their distances increase; and any optical contrivances, either of lenses or mirrors, which can alter the angle at which rays enter the eye, and make it larger than it would otherwise be, magnify the objects seen through them.

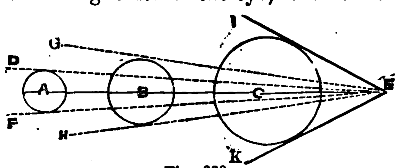


Fig. 238.

On these principles concave mirrors and convex lenses magnify, and convex mirrors and concave lenses minify.

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* The recent researches of Mr. Layard, at Nineveh, tend to prove the antiquity of magnifying-glasses. He discovered one possessing this property in one of the temples; and Sir David Brewster, who has inspected it, pronounces that it is a decided and designed magnifying-glass. The opinion of the philosopher confirms the previous supposition of Mr. Layard and various students, that the cuneiform and many other inscriptions, and also the smaller sculptures, which are so minute as to be almost unintelligible without a magnifying-glass, could only have been executed by the aid of powerful magnifying-glasses.

From their property of converging parallel rays to a focus, convex lenses and concave mirrors have an interesting application, being used for the production of high temperatures, by converging the rays of the sun. Our illustration represents such a burning-glass. The parallel rays of the sun falling on it are made to converge, and this convergence may be increased by a second smaller lens. At the focal point any small object being exposed, its temperature is instantly raised. In such a focus there are few substances that can withstand the heat—brick, slate, and other such earthy matters instantly boil; metals melt, and even volatilize away. During the last century some French chemists, using one of these instruments, found that when a piece of silver was held over gold fused at the focus, it became gilded over by the vapour that rose from the melted mass; and in the same way gold could be whitened by the vapours of melted silver. The heat attained in this way far exceeds that of the best constructed furnace.

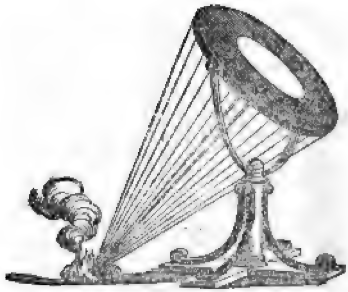

Fig. 239.

CHAPTER XXXIX.

OF COLOURED LIGHT.

Action of the Prism—Refraction and Dispersion—The Solar Spectrum—Its Constituent Rays—They pre-exist in White Light—Theory of the Different Refrangibility of the Rays of Light—Different Dispersive Powers—Irrationality of Dispersion—Illuminating Effects—The Fixed Lines—Calorific Effects—Chemical Effects.

In speaking of the action of a prism in Chapter XXXVII., it was observed that it gives rise to many interesting results connected with coloured lights. These, which constitute one of the most splendid discoveries of Newton, I next proceed to explain.

Through an aperture, *a*, Fig. 240, in the shutter of a dark room let a beam of light, *a e*, enter, and let it be intercepted at some part of its course by a glass prism, seen endwise, *b c*. The light will undergo refraction, and in consequence of what has been already stated, will pass in a direction, *d*, toward the back of the prism. Now, for anything that has yet been said, it might appear that this refracted ray, on reaching the screen, *d e*, would form upon it a white spot similar to that which it would have given at *e*, had not the prism intervened. But when the experiment is made, instead of the light going as a single pencil of uniform width, it spreads

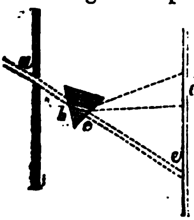

Fig. 240.

out into a fan shape, as is indicated by the dotted lines, and forms on the screen an oblong image of the most splendid colours. In this beautiful result, two facts, which are wholly distinct, must be remarked:—1st, the light is *refracted* or bent out of its rectilinear path; 2nd, it is *dispersed* into an oblong coloured figure.

On examining this figure or image, which passes under the name of the solar spectrum, we find it divided into seven well-marked regions. Its lowest portion, that is to say, the part nearest to that to which the light would have gone had not the prism intervened, is of a red colour, the most distant is of a violet, and between these other colours may be seen occurring in the following order: red, orange, yellow, green, blue, indigo, violet.

In Fig. 241 the order in which they occur is indicated by their initial letters, *e* being the point to which the light would have gone had not the prism intervened.

Now, from what source do these splendid colours come? Newton proved that they pre-existed in the white light, which, in reality, is made up of them all taken in proper proportions.

Fig. 241.

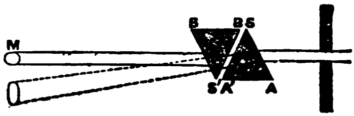

Fig. 242.

There are many ways in which this important truth can be established. Thus, if we take a second prism, B B′ S′, Fig. 242, and put it in an inverted position as respects the first, A A′ S, so that it shall refract again in the opposite direction in the rays refracted by the first, they will, after this second refraction, reunite and form a uniform beam, M, of white light, in all respects like the original beam itself.

If the production of colour were due to any irregular action of the faces of the first prism, the introduction of two more faces in the second prism would only tend to increase the coloration. But so far from this, no sooner is this second prism introduced than the rays reunite and recompose white light. It follows as an inevitable consequence that *white light contains all the seven rays.*

But Newton was not satisfied with this. He further collected the prismatic coloured rays together into one focus by means of a lens, and found that they produced a spot of dazzling whiteness. And when he took seven powders of colours corresponding with the prismatic rays, and ground them intimately together in a mortar, he found that the resulting powder had a whitish aspect; or if, on the surface of a wheel which could be made to spin round very fast on its axis, coloured spaces were painted, when the wheel was made to turn so that the eye could no longer distinguish the separate tints, the whole assumed a whitish-gray appearance.

By many experiments Newton proved that the true cause of this development of brilliant colours from a ray of white light by the prism is due to the fact that that instrument does not refract all the colours alike. Thus it could be completely shown, in the case of any transparent medium, that the violet ray was far more refrangible than the red, or more disturbed by such a medium from its course. In this originated the doctrine of "the different refrangibility of the rays of light."

On examining the order of colours in the spectrum, we find, in reality, as in Fig. 241, that the red is least disturbed from its course, and the other colours follow in a fixed order. The red, therefore, is spoken of as the least refrangible ray, the violet as the most, and the other colours as intermediately refrangible.

We now see the cause of the development of these colours from white light, which contains them all. If the prism acted on every ray alike, it would merely produce a white spot at *d*, analogous to that at *e*, Fig. 241; but as it acts unequally, it separates the coloured rays from one another, and gives rise to the spectrum.

On examining prisms of different transparent media, we find that they act very differently—some dispersing the rays far more powerfully than others, and giving rise, under the same circumstances, to spectra of very different lengths. In the treatises on optics, tables of the dispersive powers of different transparent bodies are given; thus it appears that oil of cassia is more dispersive than rock-salt, rock-salt more than water, and water more than fluor spar.

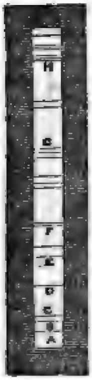

Fig. 243.

Moreover, in many instances, it has been found that if we use different prisms which give spectra of equal lengths, the coloured spaces are unequally spread out. This shows that media differ in their refracting action upon particular rays, some acting upon one colour more powerfully than another. This is called irrationality of dispersion.

The different coloured rays of light are not equally luminous—that is to say, do not impress our eyes with an equal brilliancy. If a piece of finely-printed paper be placed in the spectrum, we can read the letters at a much greater distance in the yellow than in the other regions, and from this the light declines on either hand, and gradually fades away in the violet and the red.

It has also been found that the colours are not continuous throughout, but that when delicate means of examination are resorted to, the spectrum is seen to be crossed with many hundreds of dark lines, irregularly scattered through it. A representation of some of the larger of these is given in Fig. 243. It is curious that though they exist in the sun-light, and in that of the planets, they are not found in the spectra of ordinary artificial lights; and, indeed, the electric spark gives a light which is crossed by brilliant lines instead of black ones. The chief fixed lines are designated by the letters of the alphabet, as shown in the figure.

The light of the sun is accompanied by heat. Dr. Herschel found that the different coloured prismatic spaces possess very different power over the thermometer. The heat is least in the violet, and continually increases as we descend through the colours, the red being the hottest of them all. But below this, and out of the spectrum, when there is no light at all, the maximum of heat is found. The heat of the sunbeam is therefore refrangible, but is less refrangible than the red ray of light.

Late discoveries have shown that every ray of light can produce specific changes in compound bodies. Thus it is the yellow ray which controls the growth of plants, and makes the leaves turn green; the blue ray which brings about a peculiar decomposition of the iodides and chlorides of silver, bodies which are used in photogenic drawing. Those substances which

phosphoresce after exposure to the sun are differently affected by the different rays—the more refrangible producing their glow, and the less extinguishing them.

CHAPTER XL.

OF COLOURED LIGHT.

Properties of Homogeneous Light—Formation of Compound Colours—Chromatic Aberration of Lenses—Achromatic Prism—Achromatic Lens—Imperfect Achromaticity from Irrationality of Dispersion—Cause of the Colours of Opaque Objects—Effects of Monochromatic Lights—Colours of Transparent Media.

EACH colour of the prismatic spectrum consists of homogenous light. It can no longer be dispersed into other colours, or changed by refraction in any manner. Thus, let a ray of light, S, Fig. 244, enter through an aperture, F, into a dark room, and be dispersed by the prism, A B C; through a hole, G, in a screen, D E, let the resulting spectrum pass, and be received on a second screen, *d e*, placed some distance behind; in this let there be a small opening, *g*, through which one of the coloured rays of the spectrum, formed by A B C, may pass and be received on a second prism, *a b c*; it will undergo refraction, and pass to the position M on the screen, N M. But it will not be dispersed, nor will new colours arise from it; and it is immaterial which particular ray is made to pass the opening at *g*, the same result is uniformly obtained.

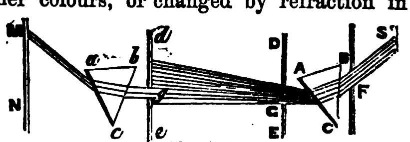

Fig. 244.

Homogeneous or monochromatic colours, therefore, cannot suffer dispersion.

By the aid of the instrument, Fig. 245, which consists of a series of little plane mirrors set upon a frame, we can demonstrate, in a very striking manner, the constitution of different kinds of lights; for if this instrument be placed in such a manner as to receive the prismatic spectrum, by turning its mirrors in a suitable position, we can throw the rays they receive at pleasure on a screen. Thus, if we mix together the red and blue ray, a purple results; if the red and yellow, an orange; and if the yellow and blue, a green. It is obvious, therefore, that of the colours we have enumerated in Chapter XXXIX. as the seven prismatic rays, the green, the indigo, and violet may be compound, or secondary ones, arising from the intermixture of red, yellow, and blue, which by many philosophers are looked upon as the three primitive colours.

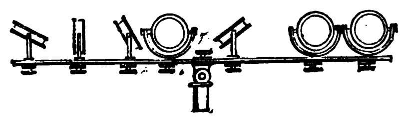
Fig 245.

We have already remarked that there is an analogy between prisms and

lenses in their action on the rays of light, and have shown how rays become converging or diverging in their passage through those transparent solids. In the same manner it also follows, that as prisms produce dispersion as well as refraction, so, too, must lenses; for, by considering the action of pairs of prisms, as in Fig. 246, or as we have already done in Chapter XXXVIII., we arrive at the action of concave and convex lenses, and find that as refrangibility differs for different rays—being least for the red, and most for the violet—a lens acting unequally will cause objects to be seen through it fringed with prismatic colours. This phenomenon passes under the title of chromatic aberration of lenses.

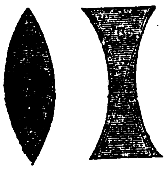

Fig. 246.

To understand more clearly the nature of this, let parallel rays of red light fall upon a plano-convex lens, A B, Fig. 247, and be converged by it to a focus in the point *r*, the distance of which from the lens is measured. Then let parallel rays of violet light, in like manner, fall on the lens, and be converged by it to a focus, *v*. On being measured it will be found that this focus is much nearer the lens than the other; and the cause of it is plainly due to the unequal refrangibility of the two kinds of light. The violet is the more refrangible, and is, therefore, more powerfully acted on by the lens, and made to converge more rapidly.

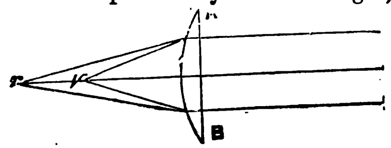

Fig. 247.

But this which we have been tracing in the case of homogeneous rays must of course take place in the compound white light. On the same principle that the prism separates the white light into its constituent rays by acting unequally on them, so, too, will the lens. Parallel rays of white light falling on a lens, such as Fig. 247, are not, therefore, converged to one common focus, as represented in Chapter XXXVIII., but in reality give rise to a series of foci of different colours, the red being the most remote from the lens, and the violet nearest.

In some of the most important optical instruments it is absolutely necessary that this defect should be avoided, and that a method should be hit upon by which light may be refracted without being dispersed. Newton, who believed that it was impossible to succeed with this, gave up the improvement of the refracting telescope, in which it is required that images should be formed without chromatic dispersion, as hopeless. But, subsequently, it was shown that refraction without dispersion can be effected. This is done by employing two bodies having equal refractive, but unequal dispersive powers. Those which are commonly selected are crown and flint glass, which refract nearly equally; the index for crown being about 1·53, and that of flint 1·60; but the dispersion of good flint glass is twice that of crown.

If, now, we take two prisms, A B C, Fig. 248, being of crown, and A C D of flint glass, and place them with their bases in opposite ways, the refracting angle, C, of the latter being half that of A, the former, or, in other words, adjusted to their relative dispersive powers, it will be found

that a ray of light passes through the compound prism, undergoing refraction, and emerging without dispersion; for the incident ray, in its passage through the crown prism, will be dispersed into the coloured rays, and these, falling on the flint prism—the dispersive power of which we assume to be double, and acting in the opposite direction—will be refracted in the opposite direction, and emerge undispersed. Such an instrument is called an achromatic prism.

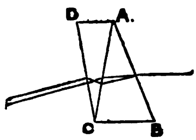

Fig. 248.

The same principle can, of course, be used in the construction of lenses, between which and prisms there is that general analogy heretofore spoken of. The achromatic lens consists of a concave lens of flint and a convex one of crown, the curvatures of each being adjusted on the same principle as the angles of the achromatic prism are determined. Such an arrangement is represented in Fig. 249. It gives in its focus the images of objects in their natural colours, and nearly devoid of fringes. But, in practice, it has been found impossible, by any such arrangement, to effect the total destruction of colour. The edges of luminous bodies seen through such lenses are fringed with colour to a slight extent. This arises from the circumstance that the dispersive powers of the media employed are not the same for every coloured ray. The simple achromatic lens, Fig. 249, will collect the extreme rays together, but leaves the intermediate ones, to a small extent, outstanding.

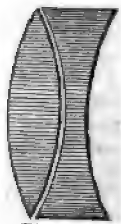
Fig. 249.

The theory of the compound constitution of light enables us to account, in a clear manner, for the colours of natural objects. Those which exhibit themselves to us as white merely reflect back to the eye the white light which falls on them, and the black ones absorb all the incident rays. The general reason of coloration is, therefore, the absorption of one or other tint, and the reflection of the rest of the spectral colours. Thus an object looks blue because it reflects the blue rays more copiously than any others, absorbing the greater part of the rest. And the same explanation applies to red or yellow, and, indeed, to any compound colours, such as orange, green, &c. That coloured bodies do, in this way, reflect one class of rays more copiously than others, may be proved by placing them in the spectrum. Thus, a red wafer seems of a dusky tint in the blue or violet regions, but of a brilliant red in the red rays.

On the same principles we account for the singular results which arise when monochromatic lights fall on surfaces of any kind. Thus, when spirits of wine is mixed with salt in a plate, and set on fire, the flame is monochromatic yellow—that is, a yellow unaccompanied by any other ray. If the variously coloured objects in a room are illuminated with such a light, they assume an extraordinary appearance: the human countenance, for example, taking on a ghastly and deathlike aspect; the red of the lips and cheeks is no longer red, for no red light falls on it; it therefore assumes a grayish tint.

The colours of transparent bodies, such as stained glass and coloured solutions, arise from the absorption of one class of rays, and the transmission of the rest. Thus there are red glasses and red solutions which permit the red ray alone to traverse them, and totally extinguish every other. But, in

most cases, the colours of transparent, and also of opaque bodies, are far from being monochromatic. They consist, in reality, of a great number of different rays. Thus the common blue-stained glass transmits almost all the blue light that falls upon it, and, in addition, a little yellow and red.

CHAPTER XLI.

UNDULATORY THEORY OF LIGHT.

Two Theories of Light—Applications of the Corpuscular Theory—Undulatory Theory—Length of Waves is the cause of Colour—Determination of the Periods of Vibration—Interference of Light—Explanations of Newton's Rings, and Colours of thin Plates—Diffraction of Light.

It has been stated that there are two different theories respecting the nature of light—the corpuscular and the undulatory. In accounting for the facts in relation to the production of colours, it is assumed that, in the former, there are various particles of luminous matter answering to the various colours of the rays, and which, either alone or by their admixture, give rise to the different tints we see. In white light they all exist, and are separated from one another by the prism, because of an attractive force which such a transparent body exerts; and that attractive force being unequal for the different colour-giving particles, difference of refrangibility results. The colours of natural objects on this theory are explained by supposing that some of the colour-giving particles are reflected or transmitted, and others stifled or stopped by the body on which they fall. The phenomena of reflection by polished surfaces are therefore reduced to the impact of elastic bodies; and in the same way that a ball is repelled from a wall against which it is thrown, so these little particles are repelled, making their angle of reflection equal to their angle of incidence. But while there are many of the phenomena of light, such as reflection, refraction, dispersion, and coloration, which can be accounted for on these principles, there are others which the emanation or corpuscular theory cannot meet. These are, however, explained in a simple and beautiful manner by the other theory.

The undulatory theory rests upon the fact that there exists throughout the universe an elastic medium called THE ETHER, in which vibratory movements can be established very much after the manner that sounds arise in the air. Whatever, therefore, has been said in Chapter XXXI., &c., respecting the mechanism and general principles of undulatory movements, applies here. Waves in the ether are reflected, and made to converge or diverge on the same principles that analogous results take place for waves upon water, or sounds in the air. It will have been observed already that the reflections of undulations from plane, spherical, elliptic, or parabolic surfaces, as given in Chapter XXXI., are identically the same as those which we have described for light in Chapter XXXVI.

From the phenomena of sound we can draw analogies which illustrate,

in a beautiful manner, the phenomena of light; for, as the different notes of the gamut arise from undulations of greater or less frequency, so do the colours of light arise from similar modifications in the vibrations of the ether. Those vibrations that are most rapid impress our eyes with the sensation of violet, and those that are slower with the sensation of red. The different colours of light are, therefore, analogous to the different notes of sound.

In Chapter XXXII. it was shown how the frequency of vibration, which could give rise to any musical note, might be determined, and it appeared that the ear could detect vibrations, as sound through a range commencing with 15, and reaching as far as 48,000 in a second. The frequency of vibration in the ether required for the production of any colour has also been determined, and the lengths of the waves corresponding. The following table gives these results. The inch being supposed to be divided into ten millions of equal parts, of those parts the wave lengths are:—

For Red	light	256
Orange	,,	240
Yellow	,,	227
Green	,,	211
Blue	,,	196
Indigo	,,	185
Violet	,,	174

More recent investigations have proved the remarkable fact, that the length of the most refrangible violet wave being taken as one, that of the least refrangible red will be equal to two, and the most brilliant part of the yellow one and a half.

Knowing the length of a wave in the ether required for the production of any particular colour of light, and the rate of propagation through the ether, which is 195,000 miles in a second, we obtain the number of vibrations executed in one second, by dividing the latter by the former.

From this it appears that if a single second of time be divided into one million of equal parts, a wave of red light vibrates 458 millions of times in that short interval, and a wave of violet light 727 millions of times.

Further, whatever has been said in Chapter XXXI. in reference to the interference of waves, must necessarily, on this theory, apply to light. Indeed, it was the beautiful manner in which some of the most incomprehensible facts in optics were thus explained that has led to its almost universal adoption in modern times. That light added to light should produce darkness seems to be entirely beyond explanation on the corpuscular theory; but it is as direct a consequence of the undulatory as that sound added to sound may produce silence.

From a lucid point, *p*, Fig. 250, let rays of light fall upon a double prism, *m n*, the angle of which, at C, is very obtuse. From what has been said respecting the multiplying-glass (Chapter XXXVII.), it appears that an eye applied at *a* would see the point *p* double, as at p' and p''. Between these images there is also perceived a number of bright and dark lines perpendicular to a line joining p' and p''. On covering one-half the prism the lines disappear, and only one image is seen.

This alternation of light and darkness is caused by ethereal waves from the points p' and p'' crossing one another, and giving rise to interference. If, therefore, with those points as centres, we draw circular arcs, 0, 1,

2, 3, 4, &c., these may represent waves, the alternate lines between them being half waves. It will be perceived that wherever two whole waves or two half waves encounter, they mutually increase each other's effect; but if the intersection takes place at points where the vibrations are in opposite directions, interference, and therefore a total absence of light, results, as is marked in the figure by the large dots.

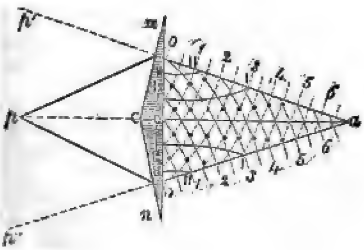

Fig. 250.

Wherever, therefore rays of light are arranged so as to encounter one another in opposite phases of vibration, interference takes place. Thus, if we take a convex lens of very long focus, and press it upon a flat glass by means of screws, Fig. 251, at the point of contact, when we inspect the instrument by reflected light, a black spot will be seen, surrounded alternately by light and dark rings. These pass under the name of Newton's coloured rings. When the light is homogeneous the dark rings are black, and the coloured ones of the tint which is employed; but when it is common white light the central black spot is surrounded by a series of colours. When the instrument is inspected by transmitted light, the colours are all complementary, and the central spot is of course white. These rings arise from the interference of the rays reflected from the anterior and posterior boundaries between the two glasses. The colours of soap-bubbles and thin plates of gypsum are referable to the same cause.

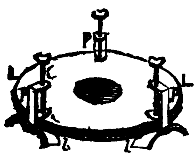

Fig. 251.

By the diffraction of light is meant its deviation from the rectilinear path, as it passes by the edges of bodies or through apertures. It arises from the circumstance that when ethereal, or, indeed, any kind of waves, impinge on a solid body, they give rise to new undulations, originating at the place of impact, and often producing interference. Thus, if a diverging beam of light passes through an aperture, *a b*, Fig. 252, in a plate of metal, an eye placed beyond will discover a series of light and dark fringes. The cause of these has already been explained in Chapter XXXI., in which it was shown that from the points *a* and *b* new systems of undulations arise, which interfere with one another, and also with the original waves.

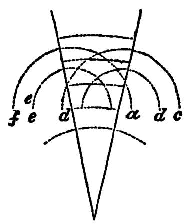

Fig. 252.

CHAPTER XLII.

OF POLARIZED LIGHT.

Peculiarity of Polarized Light—Illustrated by the Tourmaline—Polarization by Reflection—General Law of Polarization—Positions of no Reflection—Plane of Polarization.

When a ray of common light is allowed to fall on the surface of a piece of glass, it can be equally reflected by the glass upward, downward, or laterally.

If such a ray falls upon a glass plate at an angle of 56°, and is received upon a second similar plate at a similar angle, it will be found to have obtained new properties. In some positions it can be reflected as before; in others it cannot. On examination it is discovered that these positions are at right angles to one another.

Again, if a ray of light be caused to pass through a plate of *tourmaline*, *c d*, Fig. 253, in the direction *a b*, and be received upon a second plate, placed symmetrically with the first, it passes through both without difficulty. But if the second plate be turned a quarter round, as at *g h*, the light is totally cut off.

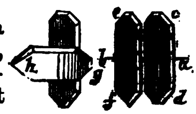

Fig. 253.

Considering these results, it therefore appears that we can impress upon a ray of light new properties by certain processes, and that the peculiarity consists in giving it different properties on different sides. Such a ray, therefore, is spoken of as a ray of polarized light.*

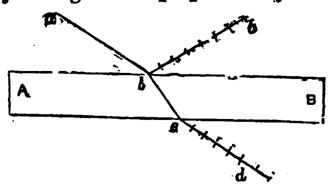

Fig. 254.

When light is polarized by reflection, the effect is only completely produced at a certain angle of incidence, which therefore passes under the name of the angle of maximum polarization. It takes place when the reflected ray makes,

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* Dr. Pareira, in his "Lectures on the Polarization of Light," delivered before the Pharmaceutical Society of London, contrasts some of the distinguishing characteristics of common and polarized light as follows:—

A RAY OF COMMON LIGHT	A RAY OF POLARIZED LIGHT
1. Is capable of *reflection* at oblique angles of incidence in every position of the reflector.	1. Is capable of *reflection* at oblique angles of incidence in *certain positions* only of the reflector.
2. Penetrates a plate of *tourmaline* (cut parallel to the axis of the crystal) in every position of the plate.	2. Penetrates a plate of *tourmaline* (cut parallel to the axis of the crystal) in certain positions of the plate, but in others is wholly intercepted.
3. Penetrates *a bundle of parallel glass plates* in every position of the bundle.	3. Penetrates a *bundle of parallel glass plates* in certain positions of the bundle.
4. Suffers *double refraction* by Iceland spar, in every direction, except that of the axis of the crystal.	4. Does not suffer *double refraction* by Iceland spar in every direction, except that of the axis of the crystal. In certain positions it suffers single refraction only.

A reference to the second column will at once explain the question, "*What is polarized light?*"—Ed.

with the refracted ray, an angle of 90.° Thus, let A B, Fig. 254, be a plate of glass, $a\ b$ an incident ray, which, at b, is partly reflected along $b\ c$, and partly refracted along $b\ e$, emerging therefrom at $e\ d$. Now maximum polarization ensues when $c\ b\ e$ is a right angle, from which it follows that the polarizing power is connected with the refractive, the law being that "the index of refraction is the tangent of the angle of polarization."

Let A B, Fig. 255, be a plate of glass, on which a ray of light, $a\ b$, falls, and after polarization is reflected along $b\ c$; at c let it be received on a second plate, C D, similar to the former, and capable of revolving on $c\ b$, as it were on an axis. Let us now examine in what positions of this plate the polarized ray, $b\ c$, can be reflected, and in what it cannot.

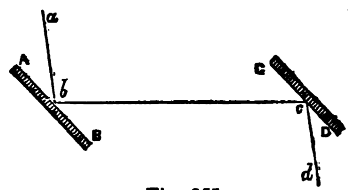

Fig. 255.

Experiment at once shows that when the plane of reflection of the first mirror coincides with the plane of reflection of the second, the polarized ray undergoes reflection; but if they are at right angles to one another, it is no longer reflected. To make this clear, let $a\ b$, Fig. 256, be the first mirror, and $c\ d$ the second, so arranged as to present their edges, as seen depicted on this page. Again, let $e\ f$ be the first, and $g\ h$ the second, now turned half-way round, but still presenting its edge; in both those positions, the planes of incidence and reflection of both the mirrors coinciding, the ray polarized by $a\ b$ or $e\ f$ will be reflected. But if, as in $i\ k$, the second mirror, l, is turned so as to present its face, or, as in $m\ n$, it is turned at o, so as to present its back, in these cases, the planes of incidence and reflection of the two mirrors being at right angles, the polarized ray can no longer be reflected. We have, therefore, two positions in which reflection is possible, and two in which it is impossible, and these are at right angles to one another. By the *plane of polarization* we mean the plane in which the ray can be completely reflected from the second mirror.

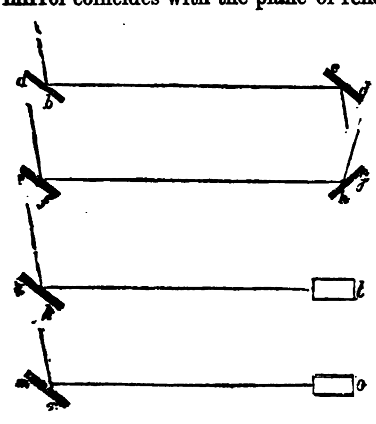
Fig. 256.

When a ray of light falls on the surface of a transparent medium, it is divided into two portions, as has already been said, one of these being reflected, and the other refracted. On examination, both these rays are found to be polarized: but they are polarized in opposite ways, or, rather, the plane of polarization of the refracted is at right angles to the plane of polarization of the reflected ray.

Polarisation by Refraction—Application of the Undulatory Theory—The Polariscope.

When it is required to polarize light by refraction, a pile of several plates

of thin glass is used, for polarization from a single surface is incomplete.

On the undulatory theory we can give a very clear account of all these phenomena. Common light originates in vibratory movements taking place in the ether; but it differs from the vibrations in the air which constitute sound in this essential particular—that while in the waves of sound the movements of the vibrating particles lie in the course of the ray, in the case of light they are transverse to it. This may be made plain by considering the wave-like motions into which a cord may be thrown by shaking it at one end, the movement being in the up-and-down, or in the lateral direction, while the wave runs straight onward. The ethereal particles, therefore, vibrate transversely to the course of the ray. But then there are an infinite number of directions in which these transverse vibrations may be made: a cord may be shaken vertically or laterally, or in an infinite number of intermediate angular positions, all of which are transverse to its length.

Common light, therefore, arises in ethereal vibrations taking place in every possible direction transverse to the path of the ray; but in polarized light the vibrations are all in one plane. Thus, in the case of *tourmaline*, when a ray passes through it all vibrations are taking place in one direction, and therefore the ray can pass through a second plate placed symmetrically with the first; but if the second be turned a quarter round the vibrations can no longer pass in the same way as a sheet of paper, *c d*, Fig. 257, may be slipped through a grating, *a b*, while its plane coincides with the length of the bars; but can no longer go through when it is turned as at *e f*, a quarter round.

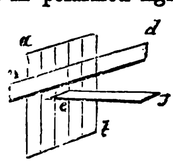

Fig. 257.

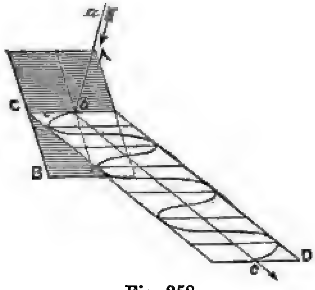

Fig. 258.

Again, in the case of polarization by reflection, let A B, Fig. 258, be the mirror on which a ray of common light, *a b*, falls at the proper angle of polarization, and is reflected in a polarized condition along *b c*. C D will be the plane in which the ethereal particles vibrate after reflection, and the curve line drawn on it may represent the intensities of their vibrations.

So, too, in Fig. 259, we have an illustration of polarization by refraction. Let A B be a bundle of glass plates, *a b* the incident, and *c d* the polarized ray; the plane C D at right angles to the plates is the plane of polarization, and the curve drawn on it represents the intensities with which the polarized particles move.

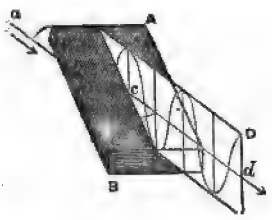

Fig. 259.

In every instance the plane of polarization is perpendicular to the planes of reflexion and refraction.

The polariscope is an instrument for exhibiting the properties of polarized light. There are many different forms of it: Fig. 260 represents one of them. It consists of a mirror of black glass, *a*, which can be set at

any suitable angle to the brass tube, A B, by means of a graduated arc, *e*; it can also be rotated on the axis of the tube, B A, and the amount of that rotation read off on the graduated circle, *b*. At the other end of the tube there is a second mirror of black glass, *d*, which, like *a*, can be arranged at any required angle, and likewise turn round on the axis of the brass tube, A B, the amount of its rotation being ascertained by the divided circle, *c*. Sometimes, instead of this mirror of black glass, a bundle of glass plates in a suitable frame is used. The instrument is supported on a pillar, C.

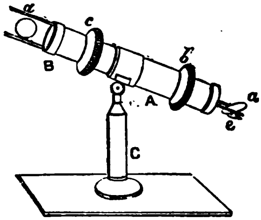

Fig. 260.

The fundamental property of light polarized by reflection may be exhibited by this instrument as follows:—Set its two mirrors, *a* and *d*, so as to receive the light which falls on them at an angle of 56°. Then, when the first, *a*, makes its reflection in a vertical plane, the light can be reflected by *d*, also in a vertical plane, upward or downward. But if *d* be turned round 90°, so as to attempt to reflect the ray to the right or left in a horizontal plane, it will be found to be impossible, the light becoming extinct and in intermediate positions. As the mirror revolves the light is of intermediate intensity.

CHAPTER XLIII.

ON DOUBLE REFRACTION AND THE PRODUCTION OF COLOURS IN POLARIZED LIGHT.

Double Refraction of Iceland Spar—Axis of the Crystals—Crystal with two Axes—Production of Colours in Polarized Light—Complementary Colours produced—Colours depend on the Thickness of the Film—Symmetrical Rings and Crosses—Colours produced by Heat and Pressure—Circular and Elliptical Polarization.

BY double refraction we mean a property possessed by certain crystals, such as Iceland spar, of dividing an incident ray into two emergent ones. Let R *r*, Fig. 261, be a ray of light falling on a rhomboid of Iceland spar, A B C X, in the point *r*; it will be divided during its passage through the crystals into two rays, *r* E, *r* O, the latter of which follows the ordinary law of refraction, and therefore takes the name of the ordinary ray; the former follows a different law, and is spoken of as the extraordinary ray.

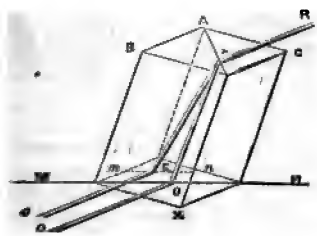

Fig. 261.

Objects through such a crystal appear double. A line, M N, on a piece

of paper, viewed through it, is exhibited as two lines, M N, *m n*, the amount of separation depending on the thickness of the crystal. The emergent rays, E *e*, O *o*, are parallel after they leave the surface, X.

A line drawn through the crystal from one of its obtuse angles to the other is called the axis of the crystal, and if artificial planes be ground and polished, as *n m*, *o p*, perpendicular to this axis, *a b*, Fig. 262, rays of light falling upon this axis, or parallel to it, do not undergo double refraction.

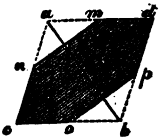

Fig. 262.

Or if new faces, *o p*, *n m*, Fig. 263, be ground and polished parallel to the axis, *a b*, a ray falling in the direction *d f* also remains single.

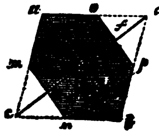

Fig. 263.

But if the refracting faces are neither at right angles nor parallel to the axis, double refraction always ensues.

While Iceland spar has only one axis of double refraction, there are other crystals, such as mica, topaz, gypsum, &c., that have two. In crystals that have but one axis there are differences. In some the extraordinary ray is inclined from the axi; in others towards it, when compared with the ordinary ray. The former are called *negative* crystals, the latter *positive*.

The explanation which the undulatory theory gives of this phenomenon in crystals having a principal axis is, that the ether existing in the crystal is not equally elastic in every direction. Undulations are therefore propagated unequally, and a division of the ray takes place, those undulations which move quickest having the less index of refraction.

When the two rays emerging from a rhomb of Iceland spar are examined, they are both found to consist of light totally polarized, the one being polarized at right angles to the other. We have, therefore, several different ways in which light can be polarized—by reflection, refraction, absorption, and double refraction.

When a crystal of Iceland spar is ground to a prismatic shape, and then achromatized by a prism of glass, it forms one of the most valuable pieces of polarizing apparatus that we have. Such a prism may be used to very great vantage, instead of the mirror of the apparatus, Fig. 260.

If a ray of polarized light is passed through a thin plate of certain crystallized bodies, such as mica or gypsum, and the light then viewed through an achromatic prism, or by reflection from the second mirror of the polarizing machine, brilliant colours are at once developed. Thus, let R A, Fig. 264, be a ray of light incident on the first mirror of the polariscope, A C the resulting polarized ray, and D E F G be a thin plate of gypsum or mica. If, previously to the introduction of this plate, the two mirrors A, and C, be crossed, or at right angles to one another, the eye placed at E will perceive no light; but, on the introduction of the crystal, its surface appears to be covered with brilliant colours, which change their tints according as it is inclined, or as the light passes through thicker or thinner places. On further examination it will be found that there are two lines, D E and F G, which, when either of them is parallel or perpendicular to

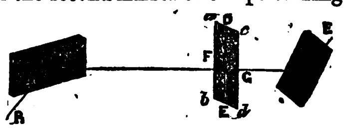

Fig. 264.

the plane of polarization, R A C, or A C E, no colours are produced. But if the plate be turned round in its own plane a single colour appears, which becomes most brilliant when either of the lines *a b*, *c d*, inclined 45° to the former ones, are brought into the plane of polarization. The former lines are called the neutral, and the latter the depolarizing axes of the film.

This is what takes place so long as we suppose the two mirrors, A C, fixed; but if we make the mirror nearest to the eye revolve while the film is stationary, the phenomena are different. Let the film be of such a thickness as to give a red tint, and be fixed in such a position as to give its maximum coloration, and the eye-mirror to revolve, it will be found that the brilliancy of the colour declines, and it disappears when a revolution of 45° has been accomplished; and now a pale green appears, which increases in brilliancy until 90° are reached, when it is at a maximum. Still continuing the revolution, it becomes paler, and at 135° it has ceased, and a red blush commences, which reaches its maximum at 180°; and the same system of changes is run through in passing from 180° to 360°; so that while the film revolves, only one colour is seen; but as the mirror revolves two appear.

If, instead of using a mirror, we use an achromatic prism, we have two images of the film at the same time, and we find that they exhibit complementary colours—that is, colours of such a tint that if they be mixed together they produce white light. This effect is represented in Fig. 265.

Fig. 265.

That the particular colours which appear, depend on the thickness of the films, is readily established by taking a thin wedge-shaped piece of sulphate of lime, and exposing it in the polariscope. All the different colours are then seen arranged in stripes according to the thickness of the film.

When a slice of an uniaxial crystal cut at right angles to the axis is used, instead of the films in the foregoing experiment, very brilliant effects are produced, consisting of a series of coloured rings, arranged symmetrically, and marked in the middle by a cross, which may either be light or dark—Figs. 266, 267—light if the second mirror is in the proper position to reflect the light from the first, and dark if it be at right angles thereto.

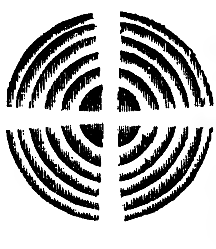

Fig. 266.

Fig. 267.

In crystals having two axes, a complicated system of oval rings, originating round each axis, may be perceived, intersected by a cross. Figs. 268, 269, represent the appearance in a crystal of

nitrate of potash; and in the same way other figures arise with different crystals.

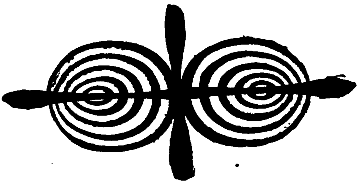

Fig. 268.

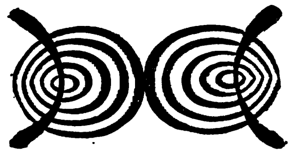

Fig. 269.

If transparent non-crystallized bodies are employed in these experiments, no colours whatever are perceived. Thus, a plate of glass, placed in the polariscope, gives rise to no such development; but if the structure of the glass be disturbed, either by warming it or cooling it unequally, or if it be subjected to unequal pressure from screws, then colours are at once developed: Figs. 270, 271. This property may, however, be rendered permanent in glass by heating until it becomes soft, and then cooling it with rapidity.

All the phenomena here described belong to the division of plane polarization; but there are other modifications which can be impressed on light, giving rise to very remarkable and intricate results; these are designated circular, elliptical, &c., polarization.

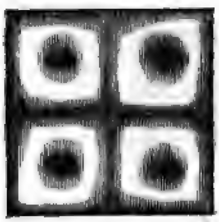

Fig. 270.

Fig. 271.

The mechanism of the motions impressed on the ether to produce these results is not difficult to comprehend; for common light, as has been stated, originates in vibrations taking place in *every* direction transverse to the ray; plane polarized light arises from vibrations in *one* direction only; and when the ethereal molecules move in circles they originate circularly polarized light, and if in ellipses, elliptical.

CHAPTER XLIV.

NATURAL OPTICAL PHENOMENA.

The Rainbow—Conditions of its Appearance—Formation of the Inner Bow—Formation of the Outer Bow—The Bows are Circular Arcs—Astronomical Refraction—Elevation of Objects—The Twilight—Reflection from the Air—Mirages and Spectral Apparitions, and Unusual Refraction.

THE rainbow, the most beautiful of meteorological phenomena, consists of one or more circular arcs of prismatic colours, seen when the back of the observer is turned to the sun, and rain is falling between him and a cloud,

which serves as a screen on which the bow is depicted. When two arches are visible, the inner one is the more brilliant, and the order of its colours is the same in which they appear in the prismatic spectrum—the red fringing its outer boundary, and the violet being within. This is called the primary bow. The secondary bow, which is the outer one, is fainter, and the colours are in the inverted order. When the sun's altitude above the horizon exceeds 42° the inner bow is not seen, and when it is more than 54° the outer is invisible. If the sun is in the horizon, both bows are semicircles, and according as his altitude is greater, a less and less portion of the semicircle is visible; but from the top of a mountain bows that are larger than a semicircle may be seen.

These prismatic colours arise from reflection and refraction of light by the drops of rain, which are of a spherical figure. In the primary bow there is one reflection and two refractions; in the secondary there are two reflections and two refractions. Thus, let S, Fig. 272, be a ray of light incident on a rain drop, *a*. On account of its obliquity to the surface of the drop, it will be refracted into a new path, and at the back of the drop it will undergo reflection, and returning to the anterior face and escaping, it will be again refracted, giving rise to violet and red, and the intermediate prismatic colours between, constituting a complete spectrum; and as the drops of rain are innumerable, the observer will see innumerable spectra arranged together so as to form a circular arc.

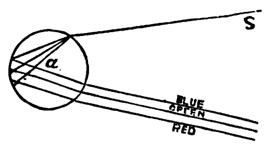

Fig. 272.

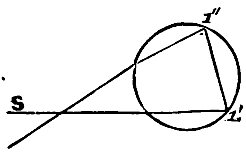

Fig. 273.

The secondary rainbow arises from two refractions and two reflections of the rays. Thus, let the ray, S, Fig. 273, enter at the bottom of the drop; it passes in the direction towards I′ after having undergone refraction at the front; from I′ it moves to I″, where it is a second time reflected, and then emerges in front, undergoing refraction and dispersion again. For the same reason as in the other case, prismatic spectra are seen arranged together in a circular arc, and form a bow.

In Fig. 274, let O be the spectator, and O P a line drawn from his eye to the centre of the bows. The rays of the sun, S S, falling on the drops, A B C, will produce the inner bow, and falling on D E F, the outer bow, the former by one, and the latter by two reflections. The drop A reflects the red, B the yellow, and C the blue rays to the eye; and in the case of the outer bow, F the red, E the yellow, and D the blue. And as the colour perceived is entirely dependent on the angle under which

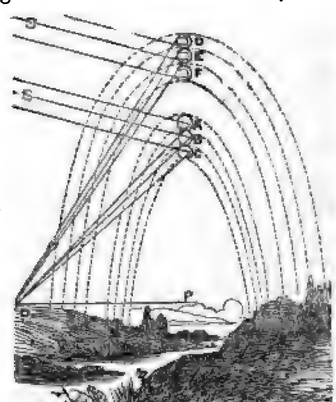

Fig. 274.

the ray enters the eye, as in the case of the interior bow, the blue entering at the angle C O P, the yellow at the larger angle B O P, and the red and the largest A O P, we see the cause why the bows are circular arcs; for out of the innumerable drops of rain which compose the shower, those only can reflect to the eye a red colour which make the same angle, A O P, that A does with the line O P, and these must necessarily be arranged in a circle of which the centre is P. And the same reasoning applies for the yellow, the blue, or any other ray as well as the red, and also for the outer as well as for the inner bow.

Another interesting natural phenomenon connected with the refraction of light is what is called "astronomical refraction," arising from the action of the atmosphere on the rays of light. It is this which so powerfully disturbs the positions of the heavenly bodies, making them appear higher above the horizon than they really are, and changes the circular form of the sun and moon to an oval shape. It also aids in giving rise to the twilight.

Let O, Fig. 275, be the position of an observer on the earth, Z will be his zenith, and let R be any star, the rays from which come, of course, in straight lines, such as R E. Now, when such a ray impinges on the atmosphere at *s*, it is refracted, and deviates from its rectilinear course. At first this refraction is feeble; but the atmosphere continually increases in density as we descend in it, and therefore the deviation of the ray from its original path, R E, becomes continually greater. It follows a curvilinear line, and finally enters the eye of the observer at O.

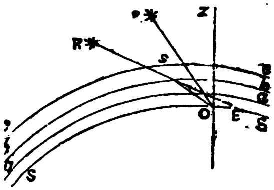

Fig. 275.

This may perhaps be more clearly understood by supposing the concentric circles *a a*, *b b*, *c c*, represented in the figure, to stand for concentric shells of air of the same density, the ray at its entry on the first becomes refracted, and pursues a new course to the second. Here the same thing again takes place, and so with the third and other ones successively. But these abrupt changes do not occur in the atmosphere, which does not change its density from stratum to stratum abruptly, but gradually and continually. The resulting path of the ray is, therefore, not a broken line, but a continuous curve.

Now, it is a law of vision that the mind judges of the position of an object as being in the direction in which the ray by which it is seen enters the eye. Consequently the star, R, which emits the ray we have under consideration, will be seen in the direction O *r*—that being the direction in which the ray entered the eye—and therefore the effect of astronomical refraction is to elevate a star or other object above the horizon to a higher apparent position than that which it actually occupies. Astronomical refraction is greater according as the object is nearer the horizon, becoming less as the altitude increases, and ceasing in the zenith. An object seen in the zenith is, therefore, in its true position.

On these principles the figure of the sun and moon, when in the horizon, changes to an oval shape; for the lower edge being more acted upon than the upper, is therefore relatively lifted up, and those objects made less in their vertical dimensions than in their horizontal. Even when an object is below the horizon, it may be so much elevated as to be brought into view; for just in the same way that a star, R, is elevated to *r*, so may one beneath

the horizon be elevated even to a greater extent, because refraction increases as we descend to the horizon. Stars, therefore, are visible before they have actually risen, and continue in sight after they have actually set. They are thus lifted out of their true position when in the horizon about thirty-three minutes. In the books on astronomy, tables are given which represent the amount of refraction for any altitude.

What has been here said in relation to a star holds also for the sun, which therefore is made apparently to rise sooner and set later than what is the case in reality. From this arises the important result that the day is prolonged. In temperate climates this lengthening of the day extends only to a few minutes; in the polar regions the *day* is made longer by a *month*. And it is for this cause, too, that the morning does not suddenly break just at the moment the sun appears in the horizon, and the night set in the instant he sinks; but the light gradually fades away as a twilight, the rays being bent from their path, and the scattering ones which fall on the top of the atmosphere brought in curved directions down to the lower parts.

The phenomenon of twilight is not, however, wholly due to refraction. The reflecting action of the particles of the air is also greatly concerned in producing it. The manner in which this takes place is shown in Fig. 276, where A B C D represents the earth, T R P the atmosphere, and S O, S′N, S′′M, rays of the sun passing through it. To an observer at the point A, the sun, at S′′, is just set; but the whole hemisphere above him, P R T, being his sky, reflects the rays which are still falling upon it, and gives him twilight. To an observer at B the sun has been set for some time, and he is in the earth's shadow; but that part of his sky which is included between P Q R *x* is still receiving sun-rays, and reflecting them to him. To an observer at C the illuminated portion of the sky has decreased to P Q *z*. His twilight, therefore, has nearly gone. To an observer at D, whose horizon is bounded by the line D P, the sky is entirely dark, no rays from the sun falling on it. It is therefore night.

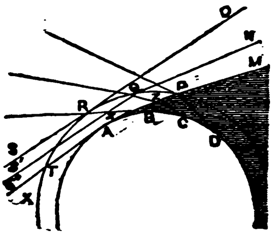

Fig. 276.

The action of the atmosphere sometimes gives rise to curious spectral appearances —such as inverted images, looming, and the mirage. The latter, which often occurs on hot sandy plains, was frequently seen by the French during their expedition to Egypt, giving rise to a deceptive appearance of great lakes of water resting on the sands. It appears to be due to the partial rarefaction of the lower strata of air through the heat of the surface on which they rest, so that rays of light are made to pass in a curvilinear path, and enter the eye. In the same

Fig. 277.

way at sea, inverted images of ships floating in the air are often discovered.

Thus, "on the first of August, 1798, Dr. Vince observed at Ramsgate a ship which appeared as at A, Fig. 277, the topmast being the only part of it seen above the horizon. An inverted image of it was seen at B, immediately above the real ship at A, and an erect image at C, both of them being complete and well defined. The sea was distinctly seen between them, as at V W. As the ship rose to the horizon, the image, C, gradually disappeared; and, while this was going on, the image, B, descended, but the mainmast of B did not meet the mainmast of A. The two images, B C, were perfectly visible when the whole ship was actually below the horizon."

These singular appearances, which have often given rise to superstitious legends, may be imitated artificially. Thus, if we take a long mass of hot iron, and, looking along the upper surface of it at an object not too distant, we shall see not only the object itself, but also an inverted image of it below; the second image being caused by the refraction of the rays of light passing through the stratum of hot air, as is the case of the mirage.

The trembling which distant objects exhibit, more especially when they are seen across a heated surface, is, in like manner, due to unusual and irregular refraction taking place in the air.

CHAPTER XLV.

THE ORGAN OF VISION.

The Three Parts of the Eye—Description of the Eye of Man—Uses of the Accessory Apparatus—Optical Action of the Eye—Short and Long-Sightedness—Spectacles—Erect and Double Vision—Peculiarities of Vision —Physiological Colours.

Almost all animals possess some mechanism by which they are rendered sensible of the presence of light. In some of the lower orders, perhaps, nothing more than a diffused sensibility exists, without there being any special organ adapted for the purpose. Thus many animalcules are seen to collect, on that side of the liquid in which they live, where the sun is shining, and others avoid the light. But in all the higher tribes of life there is a special mechanism, which depends for its action on optical laws—it is the eye.

This organ essentially consists of three different parts—an optical portion, which is the eye, strictly speaking; a nervous portion, which transmits the impressions gathered by the former to the brain; and an accessory portion, which has the duty of keeping the eye in a proper working state, and defending it from injury.

In man the eyeball is nearly of a spherical figure, being about an inch in diameter. As seen in front, between the two eyelids, *d c*, Fig. 278, it exhibits a white portion of a porcelain-like aspect, *a a*; a coloured circular part, *b b*, which continually changes in width, called *the iris;* and a central black portion, which is *the pupil.*

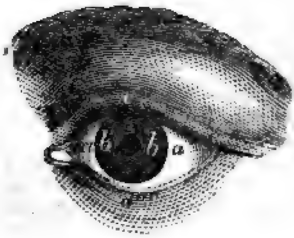

Fig. 278.

When it is removed from the orbit or socket in which it is placed, and dissected, the eye is found to consist of several coats. The white portion, seen anteriorly at *a a*, extends all round. It is very tough and resisting, and by its mechanical qualities serves to support the more delicate parts within, and also to give insertion for the attachment of certain muscles which roll the eyeball, and direct it to any object. This coat passes under the name of *the sclerotic.* It is represented in Fig. 279, at *a a a a.* In its front there is a circular aperture, into which a transparent portion, *b b*, resembling in shape a watch-glass, is inserted. This is called *the cornea.* It projects somewhat beyond the general curve of the sclerotic, as seen at *b b* in the figure, and with the sclerotic completes the outer coat of the eye.

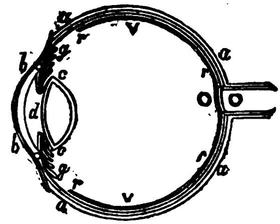

Fig. 279.

The interior surface of the sclerotic is lined with a coat which seems to be almost entirely made up of blood-vessels, little arteries and veins, which, by their internetting, cross one another in every possible direction. It is called *the choroid* coat: it extends, like the sclerotic, as far as the cornea. Its interior surface is thickly covered with a slimy pigment of a black colour, hence called *pigmentum nigrum.* Over this is laid a very delicate serous sheet, which passes under the name of *Jacob's membrane*, and the *optic nerve*, O O, coming from the brain, perforates the sclerotic and choroid coats, and spreads itself out on the interior surface, as *the retina*, *r r r r.* The optic nerves of the opposite eyes decussate one another on their passage to the brain.

These, therefore, are the coats of which the eye is composed. Let us now examine its internal structure. Behind the cornea, *b b*, there is suspended a circular diaphragm, *e f*, black behind, and of different colours in different individuals in front. This is *the iris.* Its colour is, in some measure, connected with the colour of the hair. The central opening in it, *d*, is *the pupil*, and immediately behind the pupil, suspended by the *ciliary processes*, *g g*, is the *crystalline lens*, *c c*—a double convex lens. All the space between the anterior of the lens and the cornea is filled with a watery fluid, which is the *aqueous humour;* that portion which is in front of the iris is called the *anterior chamber*, and that behind it the *posterior.* The rest of the space of the eye, bounded by the crystalline lens in front, and the retina all round, is filled with the *vitreous humour*, V V.

With respect to the accessory parts, they consist chiefly of the *eyelids*, which serve to wipe the face of the eye, and protect it from accidents and dust; the *lachrymal apparatus*, which serves to wash it with *tears*, so as to keep it continually brilliant; and the *muscles*, requisite to direct it upon any point.

Of the nervous part of the eye, so far as its functions are concerned, but little is known. The retina receives the impressions of the light, which are conveyed along the optic nerve to the brain.

Now, as respects the optical action of the eye, it is obviously nothing more than that of a convex lens, with which, indeed, its structure actually corresponds; and as in the focus of such a convex lens objects form images, so by the conjoint action of the cornea and crystalline, the images of the things to which the eye is directed form at the proper focal distance behind—that is, upon the retina. Distinct vision only takes place when the cornea and the lens have such convexities as to bring the images exactly upon the retina.

In early life it sometimes happens that the curvature of these bodies is too great, and the rays converging too rapidly, form their images before they have reached the posterior part of the eye, giving rise to the defect known as short-sightedness—a defect which may be remedied by putting in front of the cornea a concave glass lens of such concavity as just to compensate for the excess of the convexity of the eye.

In old age, on the contrary, the cornea and the lens become somewhat flattened, and they cannot converge the rays soon enough to form images at the proper distance behind. This long-sightedness may be remedied by putting in front of the cornea a convex lens, so as to help it in its action.

Concave or convex lenses, thus used in front of the eyes, constitute spectacles. It is believed that this application was first made by Roger Bacon, and it unquestionably constitutes one of the most noble contributions which science has ever made to man. It has given sight to millions who would otherwise have been blind.*

The image which is formed by a convex lens being inverted as respects its object, so must the images which form at the bottom of the eye. It has, therefore, been a question among optical writers, why we see objects in their natural position, and also why we do not see double, inasmuch as we have two eyes. Various explanations of these facts have been offered, chiefly founded upon optical principles. None, however, appear to have given general satisfaction, and in reality, the true explanation, I believe, will be found not in the optical, but in the nervous part of the visual organs. It is no more remarkable that we see single, having two eyes, than that we hear single, having two ears. It is the simultaneous arrival in the brain that gives rise out of two impressions to one perception, and accordingly, when we disturb the action of one of the eyes by pressing on it, we at once see double.

Among the peculiarities of vision it may be mentioned, that for an object

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* A defect, and not an uncommon one, with some persons, consists in the eyes refracting the rays of light with different powers in different places. The defect may be detected by making a small pin-hole in a card, which is to be moved from close to the eye to an arm's length, while the gaze is directed toward the sky, or some bright object. If the sight be perfect the hole does not alter its circular form at all; but if the peculiar defect exists, the hole becomes elongated, and ultimately merges into a straight line. M. Airey considers that a spherical cylindrical lens will correct the defect, as it succeeded in his own case.—ED.

to be seen it must be of certain magnitude, and remain on the retina a sufficient length of time; and, for distinct vision, must not be nearer than a certain distance, as eight or ten inches. This distance of distinct vision varies somewhat with different persons. The eye, too, cannot bear too brilliant a light, nor can it distinguish when the rays are too feeble; though it is wonderful to what an extent, in this respect, its powers range. We can read a book by the light of the sun or the moon; yet the one is a quarter of a million times more brilliant than the other. Luminous impressions made on the retina last for a certain space of time, varying from one-third to one-sixth of a second. For this reason, when a stick, with a spark of fire at the end, is turned rapidly round, it gives rise to an apparent circle of light.

By accidental or physiological colours we mean such as are observed for a short time depicted on surfaces, and then vanishing away. Thus, if a person looks steadfastly at a sheet of paper strongly illuminated by the sun, and then closes his eyes, he will see a black surface corresponding to the paper. So if a red wafer be put on a sheet of paper in the sun, and the eye suddenly turned on a white wall, a green image of the wafer will be seen. Spectral illusions in the same way often arise—thus, when we awake in the morning, if our eyes are turned at once to a window brightly illuminated, on shutting them again we shall see a visionary picture of every portion of the window, which after a time fades away.

CHAPTER XLVI.

OF OPTICAL INSTRUMENTS.

The Common Camera Obscura—The Portable Camera—The Single Microscope—The Compound Microscope—Chromatic and Spherical Aberration—The Magic Lantern—The Solar Microscope—The Oxihydrogen Microscope.

In this and the next chapter I shall describe the more important optical instruments. These, in their external appearance, and also in their principles, differ very much according to the taste or ideas of the artist. The descriptions here given will be limited to such as are of a simple kind.

The Camera Obscura, or dark chamber, originally consisted of nothing more than a double convex lens of a foot or two in focus, fixed in the shutter of a dark room. Opposite the lens, and at its focal distance, a white sheet received the images. These represent whatever is in front of the lens, giving a beautiful picture of the stationary and movable objects in their proper relation of light and shadow, and also in their proper colours.

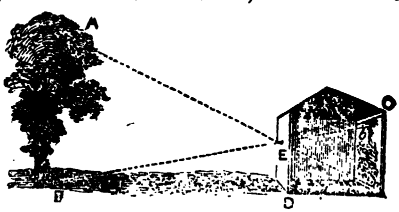


Fig. 280.

In point of fact, a lens is not required: for if, into a dark chamber, C D, Fig. 280, rays are admitted through a small aperture, L, an inverted image will be formed, on a white screen at the back of the

chamber, of whatever objects are in front. Thus the object, A B, gives the inverted image, *b a*. These images are, however, dim, owing to the small amount of light which can be admitted through the hole. The use of a double convex lens permits us to have a much larger aperture, and the images are correspondingly brighter.

The portable Camera Obscura consists of an achromatic double convex lens, *a a'*, set in a brass mounting in the front of a box consisting of two parts, of which *c c'* slides in the wider one, *b b'*. The total length of the box is adjusted to suit the focal distance of the lens. In the back of the part, *c c'*, there is a square piece of ground glass, *d*, which receives the images of the objects to which the lens is directed, and by sliding the movable part in or out, the ground glass can be brought to the precise focus. The interior of the box and brass piece, *a a'*, is blackened all over to extinguish any stray light.

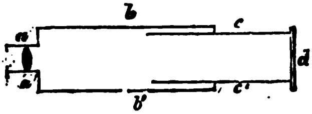


Fig. 281.

The images of the camera are, of course, inverted; but they can be seen in their proper position by receiving them on a looking-glass, placed so as to reflect them upward to the eye. Objects that are near, compared with objects that are distant, require the back of the box to be drawn out, because the foci are further off. Moreover, those that are near the edges are indistinct, while the central ones are sharp and perfect. This arises from the circumstance that the edges of the ground glass are further from the lens than the central portion, and therefore out of focus.

OF MICROSCOPES.

The Single Microscope.—When a convex lens is placed between the eye and an object situated a little nearer than its focal distance, a magnified and erect image will be seen.

The single microscope consists of such a lens, *m*, Fig. 282, the object, *b c*, being on one side, and the eye, *a*, at the other, a magnified and erect image, B C, is seen. The linear magnifying power of such a lens is found by dividing the distance of distinct vision by its focal length.

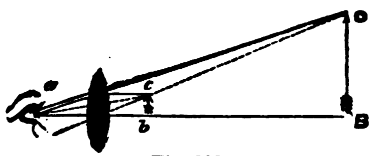


Fig. 282.

The Compound Microscope commonly consists of three lenses, A B, E F, C D, Fig. 283, A B being the object-glass, E F the field-glass, and C D the eye-glass. Beyond the object-glass is placed the object, at a distance somewhat greater than the focal length; a magnified image is, therefore, produced, and this being viewed by the eye-glass is still further magnified, and, of course, seen in an inverted position. The use of the field-glass is to intercept the extreme pencils of light, *n m*, coming from the object-glass, which

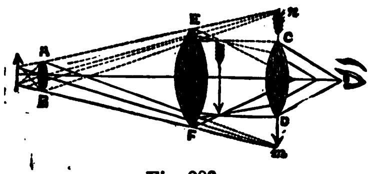


Fig. 283.

would otherwise not have fallen on the eye-lens. It therefore increases the field of view, and hence its name.

In this instrument the object-glass has a very short focus; the eye-glass, one that is much larger; and the field-glass and the eye-glass can be so arranged as to neutralize chromatic aberration.

To determine directly the magnifying power of this instrument, an object, the length of which is known, is placed before it. Then one eye being applied to the instrument, with the other we look at a pair of compasses, the points of which are to be opened, until they subtend a space equal to that under which the object appears. This space, being divided by the known length of the object, gives the magnifying power.

In Fig. 284, we have a representation of the compound microscope, as commonly made. A B is a sliding brass tube, which bears the eye-glass; *m n* is the object-glass; I K the field-glass; S T a stage for carrying the objects. It can be moved to the proper focal distance by means of a pinion. At V there is a mirror which reflects the light of a lamp or the sky upward, to illuminate the object. The body of the microscope is supported on the pillar M, and it can be turned into the horizontal or any oblique position to suit the observer, by a joint, N. To the better kind of instruments micrometers are attached, for the purpose of determining the dimension of objects. These are sometimes nothing more than a piece of glass, on which fine lines have been drawn with a diamond, forming divisions the value of which is known. Such a plate may be placed either immediately beneath the object or at the diaphragm, which is between the two lenses.

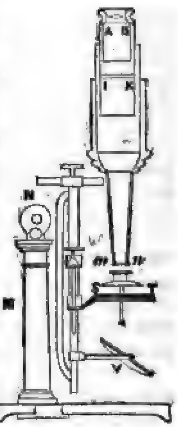


Fig. 284.

In microscopes the defective action of lenses, known as chromatic aberration, and described in Chapter XL., interferes, and, by imparting prismatic colours to the edges of objects, tends to make them indistinct. To overcome this difficulty, achromatic object-glasses are used in the finer kinds of instruments.

Besides chromatic aberration, there is another defect to which lenses are subject. It arises from their spherical figure, and hence is designated *spherical aberration*. Let P P, Fig. 285, be a convex lens, on which rays, E N, E N, E M, E M, E A, from any object, E *e*, are incident, it is obvious that the principal ray, E A, will pass on through B to F without undergoing refraction. Now, rays which are near to this, as E M, E M, converge by the action of the lens to a focus at F: but those which are more distant, and fall near the edges of the lens, as E N, E N, converge more rapidly, and come to a focus at G.

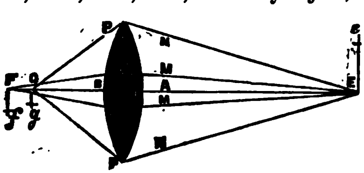


Fig. 285.

Thus images, F *f*, G *g*, are formed by the extreme rays, and an intermediate series of them by the intermediate rays, the whole arising from the peculiarity of figure of the lens. It is, indeed, the same defect as that to which spherical mirrors are liable, as explained in Chapter XXXVI.; and

hence, to obtain perfect action with a spherical lens, as with a spherical mirror, its aperture must be limited.

OF OPTICAL INSTRUMENTS.

THE MAGIC LANTERN consists of a metallic lantern, A A′ Fig. 286, in front of which two lenses are placed. One of these, *m*, is the illuminating lens, the other, *n*, the magnifier. A powerful Argand lamp is placed at L, and behind it a concave mirror, *p q*. In the space between the two lenses the tube is widened, *c d*, or such an arrangement made that slips of glass, on which various figures are painted, can be introduced. The action of the instrument is very simple. The mirror and the lens *m* illuminate the drawing as highly as possible; for the lamp being placed in their foci, they throw a brilliant light upon it, and the magnifying lens, *n*, which can slide in its tube a little backward and forward, is placed in such a position as to throw a highly magnified image of the drawing upon a screen, several feet off, the precise focal distance being adjusted by sliding the lens. As it is an inverted image which forms, it is, of course, necessary to put the drawing in the slide, *c d*, upside down, so as to have their images in the natural position. Various amusing slides are prepared by the instrument-makers, some representing bodies or parts in motion. The figures require to be painted in colours that are quite transparent.

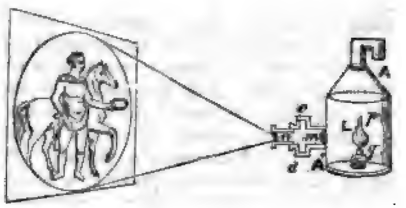


Fig. 286.

[By employing two distinct magic lanterns, or two lanterns inclosed in the same case, the dissolving views are exhibited.]

THE SOLAR MICROSCOPE.—This instrument, like the magic lantern, consists of two parts—one for illuminating the object highly, and the other for magnifying it. It consists of a brass plate, which can be fastened to an aperture in the shutter of a dark room, into which a beam of the sun may be directed by means of a plane mirror. In Fig. 287, M is the mirror, to which movement in any direction may be given by the two buttons, X and Y, that rays from the sun may be reflected horizontally into the room. They pass through a large convex lens, R, and are converged by it; they again impinge on a second lens, U S, which concentrates them to a focus, the precise point of which may be adjusted by sliding the lens to the proper position by the button B. P P′ is an apparatus consisting of two fixed plates, with a movable one, Q, between them, Q being pressed against P′ by means of spiral springs. This apparatus is for the purpose of supporting the various objects which are held by the pressure of Q against P. Immediately beyond this, at L, is the magnifying lens, or object-glass, which can be brought to the proper position from the

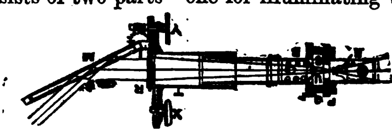


Fig. 287.

highly illuminated object by means of the button B′; and the magnified image resulting is then thrown on a screen at a distance.

The solar microscope has the great advantage of exhibiting objects to a number of persons at the same time.

In principle, the Oxihydrogen Microscope is the same as the foregoing, only, instead of employing the light of the sun, the rays of a fragment of lime ignited in the flame of an oxihydrogen blow-pipe are used. These rays are converged on the object, and serve to illuminate it. The advantage the instrument has over the solar microscope is, that it can be used at night and on cloudy days.

CHAPTER XLVII.

OF TELESCOPES.

Refracting and Reflecting Telescopes—Galileo's Telescope—The Astronomical Telescope—The Terrestrial—Of Reflecting Telescopes—Herschel's, Newton's, the Cassegrairian, Gregory's, Lord Rosse's, Mr. Lassell's, and the Craig Telescope—Determination of their Magnifying Powers—The Achromatic Telescope.

THE telescope is an instrument which, in principle, resembles the microscope, both being to exhibit objects to us under a larger visual angle. The microscope does this for objects near at hand, the telescope for those that are at a distance.

Telescopes are of two kinds, refracting and reflecting. Each consists essentially of two parts—the object-glass or objective, and the eye-piece. In the former, the objective is a lens, in the latter it is a concave mirror.

The distinctness of objects through telescopes is necessarily connected with the brilliancy of the images they give; and this, among other things, depends on the size of the objective.

There are three kinds of refracting telescopes:—1st, Galileo's; 2nd, the Astronomical; 3rd, the Terrestrial.

GALILEO'S TELESCOPE, which is represented in Fig. 288, consists of a convex lens, L N, which is the objective, and a concave eye-glass, E E. Let O B be a distant object, the rays from which are received upon L N, and by it would be brought to a focus, and give the image, M I; but, before they reach this point, they are intercepted by the concave eye-glass, E E, which make them diverge, as represented at H K, and give an erect image, *o m*. This form of telescope has an advantage in the erect position of its image, which is usually presented with great clearness. Its field of view, by reason of the divergence of the rays through the eye-glass, is limited. When made on a small scale, it constitutes the common opera-glass.

Fig. 288

THE ASTRONOMICAL TELESCOPE differs from the former in having for its eye-piece a convex lens of short focus compared with that of the object-lens. In this, as in the former instance, the office of the objective is to give an image, and the eye-

Fig. 289.

piece magnifies it precisely on the same principle that it would magnify any object. In Fig. 289, L N is the objective, and E E the eye-glass; the rays from a distant object, O B, are converged so as to give a focal image, M I. This being viewed through the eye-lens, E E is magnified, and is also inverted. The magnifying power of the telescope is found by dividing the focal length of the objective by that of the eye-lens.

This telescope, of course, inverts, and therefore is not well adapted for terrestrial objects; but for celestial ones it answers very well.

THE TERRESTRIAL TELESCOPE consists of an object-lens, like the foregoing, but in its eye-piece are three lenses of equal focal lengths. The combination is represented in Fig. 290, in which L N is the object-lens, and E E, F F, G G the eye-lenses, placed at distances from each other equal to double their focal length. The progress of the rays through the object-lens and the first eye-glass to X is the same as in the astronomical telescope; but, after crossing at X, they are received on the second eye-lens, which gives an erect image of them at *i m*, which is viewed, therefore, in the erect position by the last eye-lens, G G.

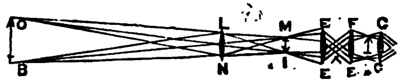


Fig. 290.

As the distance at which the image forms from the object-lens is dependent on the actual distance of the object itself, one which is near giving its image further off than one which is distant, it is necessary to have the means of adjusting the eye-piece, so as to bring it to the proper distance from the image, M I. The object-lens is therefore put in a tube longer than its own focus, and in this a smaller tube, bearing the three eye-lenses, immovably fixed, slides backward and forward; this tube is drawn out, until distinct vision of the object is attained.

REFLECTING TELESCOPES are of several different kinds. They have received names from their inventors.

HERCHEL'S TELESCOPE consists of a metallic concave mirror, set in a tube in a position inclined to the axis. It of course gives an inverted image of the object at its focus, and the inclination is so managed as to have the image form at the side of the tube. There it is viewed by an eye-lens, which shows it magnified and inverted. The back of the observer is turned to the object, and the inclination of the mirror is for the purpose of avoiding obstruction of the light by the head.

NEWTON'S TELESCOPE consists of a concave mirror, A R, Fig. 291, with its axis parallel to that of the tube, D E, F G, in which it is set. The rays reflected from it are intercepted by a plane mirror, C K, placed at an angle of 45°, on a sliding support, *m*. They are, therefore, reflected towards the side of the tube, the image, *i m*, forming at I M, an eye-glass at L magnifies it.

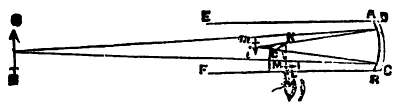


Fig. 291.

[THE CASSEGRAIRIAN TELESCOPE.—The great speculum of this instrument is perforated like the Gregorian; but the rays converging from the surface

of the mirror, A B, Fig. 292, towards the focus *a*, are intercepted before they reach that point by a small convex mirror, *d*, not sufficiently convex to make the rays divergent, but of such a curvature as to prevent them from coming to a focus till they are thrown back to *b*, near the aperture in A B, where they form an inverted image, which is viewed by the eye-piece E. This construction has the advantage of requiring a shorter tube than the Gregorian; but the inversion of the image is not corrected; and for this reason probably it has not been much used.

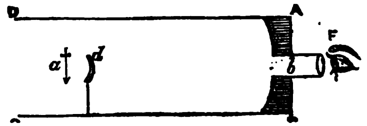


Fig. 292.

[The small mirror, *d*, is adjusted by means of a rod turning on a shoulder near the eye-end of the tube (the same as in the Gregorian telescope), and connected by a screw with the apparatus which carries the wire to which the mirror is attained.—*Brande's "Dict. of Science, Literature and Art," p.* 1220.]

THE GREGORIAN TELESCOPE has a concave mirror, A R, Fig. 293, with an aperture, L, in its centre. The rays from a distant object, O B, give, as before, an inverted image, M I. They are then received on a small concave mirror, K C, placed fronting the great one. This gives an erect image, which is magnified by the eye-lens, P.

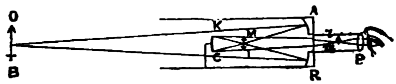


Fig. 293.

The magnifying power of any of these instruments may be roughly estimated by looking at an object through them with one eye, and directly at it with the other, and comparing the relative magnitude of the two images. In Herchel's telescope the back of the observer is toward the object, in Newton's his side, but in Gregory's he looks directly at it. The latter is, therefore, by far the most agreeable instrument to use. The largest telescopes hitherto constructed are upon the plan of Herschel and Newton.

[Lord ROSSE'S TELESCOPE, which is nearly 50 feet long, with its huge wooden tube: Mr. LASSELL'S, with its sheet-iron tube, and the CRAIG TELESCOPE, are all wonders of modern science. Our readers have already become familiar with the last instrument, as we gave a description and illustration of it in a previous section.]

When Sir Isaac Newton discovered the compound nature of light, by prismatic analysis, he came to the conclusion that the refracting telescope could never be a perfect instrument, because it appeared impossible to form an image by a convex lens, without its being coloured on the edges by the dispersion of light. He therefore turned his attention to the reflecting telescope, and invented the one which bears his name. He even manufactured one with his own hands. It is still preserved in the cabinet of the Royal Society of London.

But after it was discovered that refraction without dispersion can be effected, and that lenses can be made to form colourless images in their foci, the principle was at once applied to the telescope; and hence originated that most valuable astronomical instrument, the Achromatic Telescope.

In this the object-glass is of course compound, consisting, as represented

in Fig. 294, of one crown and one flint-glass lens; or as represented in Fig. 295, of one flint and two crown-glass lenses. The principle of its action has been described in Chapter XL. The great expense of these instruments arises chiefly from the costliness of the flint glass, for it has hitherto been found difficult to obtain it in masses of large size, perfectly free from veins or other imperfections. Nevertheless there are instruments which have been constructed in Germany, with an aperture of thirteen inches. Some of these are mounted on a frame, connected with a clock movement; so that when the telescope is turned to a star it is steadily kept in the centre of the field of view, notwithstanding the motion of the earth on her axis. Several large instruments of this description are now in the various Observatories.

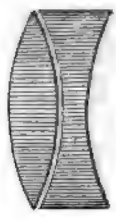


Fig. 294.

Fig. 295.

SECTION IX.—THE PROPERTIES OF HEAT.—THERMOTICS.

CHAPTER XLVIII.

THE PROPERTIES OF HEAT.

Relations of Light and Heat—Mode of Determining the Amount of Heat—The Mercurial Thermometer—Its Fixed Points—Fahrenheit's, Centigrade, Reaumur's Thermometers—The Gas Thermometer—Differential Thermometer—Solid Thermometers—Comparative Expansion of Gases, Liquids, and Solids.

WHATEVER may be the true cause of light, whether it be undulations in an ethereal medium, or particles emitted with great velocity by shining bodies, observation has clearly proved that heat is closely allied to it.

When a body is brought to a very high temperature, and then allowed to cool in a dark place, though it might be white-hot at first, it very soon becomes invisible, losing its light apparently in the same way that it loses its heat. And we shall hereafter find the rays of heat which thus escape from it may be reflected, refracted, inflected, and polarised, just as though they were rays of light.

In its general relations, heat is of the utmost importance in the system of nature. The existence of life, both vegetable and animal, is dependent on it; it determines the dimensions of all objects, regulates the form they assume, and is more or less concerned in every chemical change that takes place.

Every object to which we have access possesses a certain amount of heat, and so long as it remains at common temperatures, may be touched without pain; but if a larger quantity of heat is given to it, it assumes qualities that are wholly new, and if touched it burns.

To determine, therefore, with precision the quantity of heat which is present in a body when it exhibits any particular phenomenon, it is necessary

that we should be furnished with some means of effecting its measurement. Instruments intended for this purpose are called thermometers.

[Much doubt exists respecting the date of the invention of the thermometer, and the originator is unknown; but it is generally considered to have been invented about the beginning of the 17th century. Vast improvements have been made in its construction since the period of its adoption. To the astronomer Röemer is due the merit of having proposed mercury as the thermometer fluid, instead of the linseed-oil used by Newton. About 1724 Fahrenheit considerably improved the instrument; but since then little or no improvement has taken place in it.]

Of thermometers we have several different kinds. Some are made of solid substances, others of liquids, and others of gases. With a few exceptions they all depend on the same principle—the expansion which ensues in all bodies as their temperature rises.

Of these the Mercurial Thermometer is the most common, and for the purposes of science the most generally available. It consists of a glass tube, Fig. 296, with a bulb on its lower extremity. The entire bulb and part of the tube are filled with quicksilver, and the rest of the tube, the extremity of which is closed, contains a vacuum. This glass portion is fastened in an appropriate manner upon a scale of ivory or metal, which bears divisions, and the thermometer is said to be at that particular degree against which its quicksilver stands on the scale.

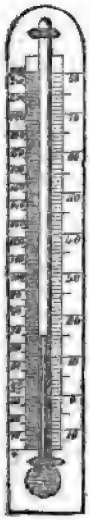


Fig. 296.

If we take the bulb of such an instrument in the hand, the quicksilver immediately begins to rise in the tube, and finally is stationary at some particular degree, generally the 98th in our thermometers. We therefore say the temperature of the hand it 98 degrees.

In effecting a measure of any kind, it is necessary to have a point from which to start and a point to which to go. The same is also necessary in making a scale. One of the essential qualities of a thermometer is to enable observers in all parts of world to indicate the same temperature by the same degree. A common system of dividing the scale must therefore be agreed upon, that all thermometers may correspond.

If we dip a thermometer in melting ice or snow, the quicksilver sinks to a certain point, and to this point it will always come, no matter when or where the experiment is made. If we dip it in boiling water, it at once rises to another point. Philosophers in all countries have agreed, that these are the best fixed points to regulate the scale by, and accordingly they are now used in all thermometers. In the Fahrenheit thermometer, which is commonly employed, we mark the point at which the instrument stands, when dipped in melting snow, 32°, and that for boiling water, 212°, and divide the intervening space into 180 parts, each of which is a degree; and these degrees are carried up to the top and down to the bottom of the scale.

[As it is often necessary to reduce the scale of one of the various thermometers in general use to the corresponding degree of another instrument, we consider that the following remarks, extracted from "Brande's Dictionary of Science, Literature, and Art," will be useful to many of our readers:—

"For the sake of perspicuity, it is convenient to adapt the expressions to

three distinct cases. Let F denote degrees of Fahrenheit's scale, C degrees of the Centigrade, and R degrees of Reaumur; then

CASE 1.—For all temperatures above the freezing point, $F - 32 = \frac{9}{5} C = \frac{9}{4} R$.

CASE 2.—For all temperatures between the freezing point and the zero of Fahrenheit's scale, $32 - F = - \frac{9}{5} C = - \frac{9}{4} R$.

CASE 3.—For all temperatures below the zero of Fahrenheit, $- 32 - F = - \frac{9}{5} C = - \frac{9}{4} R$."]

In different countries other divisions are used, adjusted, however, by the same fixed points. The Centigrade thermometer has, for the melting of ice, 0, and for the boiling of water, 100°, with the intervening space divided in 100 equal degrees. In Reaumur's thermometer, the lower point is marked 0, and the upper 80°.

The philosophical fact upon which the construction of the thermometer reposes, is, that quicksilver expands by an increase of heat, and is contracted by a diminution of it; and further, that these expansions and contractions are in proportion to the changes of temperature.

But for particular purposes thermometers have been made of oil, of alcohol, and of a great many other liquid bodies, and give rise to the same general results. As a uniform law it may therefore be asserted that all liquids dilate as their temperature rises, and contract as it descends.

But heat determines the volume of gases as well as of liquids. If we take a tube, *a*, Fig. 297, with a bulb at its upper extremity, *b*, and having partly filled the tube with a column of water, coloured, to make its movements visible, the lower end dipping loosely into some of the same coloured water, contained in a bottle, *c*; on touching the bulb, *b*, the coloured liquid in the tube is pressed down by the dilation of the air, and on cooling the bulb the liquid rises, because the air contracts. And were the bulb filled with any other gaseous substance, such as oxygen, hydrogen, &c., still the same thing would take place. So gases, like liquids, expand as their temperature rises, and contract as it descends.

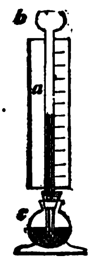


Fig. 297.

Such an instrument as Fig. 297 passes under the name of an Air Thermometer. Its indications are not altogether reliable, as may be proved by putting it under an air-pump receiver, when its column of liquid will instantly move as soon as the least change is made in the pressure of the air. It is affected, therefore, by changes of pressure as well as changes of temperature.

There is, however, a form of air thermometer which is free from this difficulty. It is the Differential Thermometer. This instrument consists of a tube, *a b*, Fig. 298, bent at right angles towards its ends, which terminate in two bulbs, *c d*. In the horizontal part of the tube is a little column of liquid marked by the black line, which serves as an index. If the bulb *c* is touched by the hand, its air dilates and presses the index column over the scale; if *d* is touched the same thing takes place, but the column moves the opposite way; if both bulbs are touched at once, then the column, pressed equally in opposite directions, does not move at all. Of course, a similar reasoning

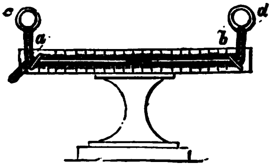


Fig. 298.

applies to the cooling of the bulbs. The instrument is therefore called a differential thermometer, because it indicates the difference of temperature between its bulbs, but not the absolute temperature to which it is exposed.

In the same manner that we have thermometers, in which the changes of volume of liquids and gases are employed, to indicate changes of temperature, so, too, we have others in which solids are used. These generally consist of a strip of metal which is connected with an arrangement of levers or wheels, by which any variations in its length may be multiplied. The disturbing agencies, thus introduced by this necessary mechanism, interfere very much with the exactness of these instruments. And hitherto they have not been employed, except for special purposes, and can never supplant the mercurial thermometer.

It being thus established that all substances, gases, liquids, and solids, expand as their temperature rises, and contract as it falls, it may next be remarked that great differences are detected when different bodies of the same form are compared. There are scarcely two solid substances which, for the same elevation of temperature, expand alike. All do expand; but some more and some less. In the case of crystalline bodies, even the same substance expands differently in different directions. Thus a crystal of Iceland spar dilates less in the direction of its longer than it does in the direction of its shorter axis. The same holds good for liquids. If a number of thermometers, *a b c*, Fig. 299, of the same size be filled with different liquids, and all plunged in the same vessel of hot water, *f*, so as to be warmed alike, the expansion they exhibit will be very different. Until recently it was believed that all gases expand alike for the same changes of temperature; but it is now known that minute differences exist among them in this respect. For every degree of Fahrenheit's thermometer atmospheric air expands $\frac{1}{493}$ of its volume at 32°.

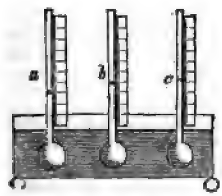


Fig. 299.

Gases, liquids, and solids compared together, for the same change of temperature, exhibit very different changes of volume; gases being the most dilatable, liquids next, and solids least of all. This probably arises from the fact that the cohesive force, which is the antagonist of heat, is most efficient in solids, less so in liquids, and still less in gases.

CHAPTER LXIX.

OF RADIANT HEAT.

Path of Radiant Heat—Velocity of Radiant Heat—Effects of Surface—Law of Reflection—Reflection by Spherical Mirrors—Theory of Exchanges of Heat—Diathermanous and Athermanous Bodies—Properties of Rock Salt—Imaginary Colouration.

EXPERIENCE shows that whenever a hot body is freely exposed its temperature descends, until eventually it comes down to that of the surrounding bodies. There are two causes which tend to produce this result. They are radiation and conduction.

All bodies, whatever their temperature may be, radiate heat from their surfaces. It passes forth in straight lines, and may be reflected, refracted, and polarised like light.

The rate at which radiant heat moves is the same, in all probability, as the rate for light. It has been asserted that its velocity is only four-fifths that of light; but this seems not to rest upon any certain foundation.

As respects the rapidity or facility with which radiation takes place, much depends on the nature of the surface. The experiments of Leslie show that, at equal temperatures, such as are smooth are far less effective than such as are rough. This result he established by taking a cubical metallic vessel, *c*, filled with hot water, the four vertical sides being in different physical conditions—one being polished, a second slightly roughened, a third still more so, and the fourth roughened and blackened. Under these circumstances, the rays of heat escaping from each surface, as it was turned in succession toward a metallic reflector, M, raised a thermometer, *d*, placed in the focus, to very different degrees, the polished one producing the least effect.

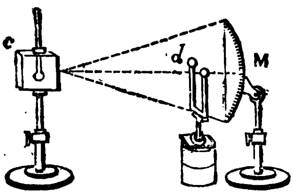


Fig. 300.

Just as light is reflected, so, too, is heat. If we take a plate of bright tin, and hold it in such a position as to reflect the light of a clear fire into the face, as soon as we see the light we also feel the impression of the heat. The law for the one is also the law for the other—"the angle of reflection is equal to the angle of incidence"—and consequently mirrors with curved surfaces act precisely in one case as they do in the other. We have already shown, Chapter XXXVI., how rays diverging from the focus of a mirror are reflected parallel, and how parallel rays falling on a mirror are converged. And it is upon that principle that we account for the following striking experiment. In the focus of a concave metallic mirror let there be placed a red-hot ball, *a*, Fig. 301; the rays of heat diverging from it in right lines, *a c*, *a d*, *a e*, *a f*, will be reflected parallel in the lines *c g*, *d h*, *e i*, *f k*, and, striking upon the opposite mirror, will all converge to *b*, in its focus. If, therefore, at this point any small combustible body, as a piece of phosphorus, be placed, it will instantly take fire, though a distance of twenty or fifty feet may intervene between the mirrors. Or, if the bulb of an air thermometer be used instead of the phosphorus, it will give at once the indication of a rapid elevation of temperature.

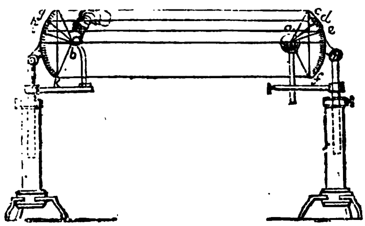


Fig. 301.

But this is not all; for if, still retaining the thermometer in its place, we remove away the red-hot ball and replace it by a mass of ice, the thermometer instantly indicates a descent of temperature—the production of cold. At one time it was supposed that this was due to cold rays which escaped from the ice, after the same manner as rays of heat; but it is now admitted that the effect arises from the circumstance that the thermometer

bulb, being warmer than the ice, radiates its heat to the ice, the temperature of which ascends precisely in the same manner as that in the former experiment; the red-hot ball, being the warmer body, radiated its heat to the thermometer.

In fact, these experiments are nothing more than illustrations of a theory which passes under the name of "The Theory of the Exchanges of Heat." This assumes that all bodies are at all times radiating heat to one another; but the speed with which they do this depends upon their temperature, a hot body giving out heat much faster than one the temperature of which is lower. Thus, if we have a red-hot ball and a thermometer bulb in presence of one another, the ball, by reason of its high temperature, will give more heat to the bulb than it receives in return; its temperature will therefore descend while that of the bulb rises. But if the same bulb be placed in presence of a mass of ice, the ice will receive more heat than it gives, because it is the colder body of the two, and the temperature of the thermometer therefore declines.

All bodies are at all times radiating heat, their power of radiation depending on their temperature, increasing as it increases, and diminishing as it diminishes.

As is the case with light, so, too, with heat; there are substances which transmit its rays with readiness, and others which are opaque. We therefore speak of diathermanous bodies, which are analogous to the transparent, and athermanous, which are like the opaque. Among the former, a vacuum and most gaseous bodies may be numbered; but it is remarkable that substances which are perfectly transparent to light are not necessarily so to heat. Glass, which transmits, with but little loss, much of the light which falls on it, obstructs much of the heat; and, conversely, smoky quartz and brown mica, which are almost opaque to light, transmit heat readily. But of all solid substances, that which is most transparent to heat, or most diathermanous, is rock salt; it has therefore been designated as the glass of radiant heat. If a prism be cut from this substance, and a beam of radiant heat allowed to fall upon it, it undergoes refraction and dispersion precisely as we have already described as occurring under similar circumstances with a glass prism for light in Chapter XXXIX. And if convex lenses be made of rock salt they converge the rays of heat to foci, at which the elevation of temperature may be detected by the thermometer. Heat, therefore, can be refracted and dispersed as easily as it can be reflected.

If we take a convex lens of glass and one of rock salt, and cause them to form the image of a burning candle in their foci, it will be found on examination that the image through the rock salt is hot, but that through the glass can scarcely affect a delicate thermometer. This experiment sets in a clear light the difference in the relations between glass and salt, the former permitting the light to pass, but not the heat, the latter transmitting both together.

When light is dispersed by a prism, the splendid phenomenon of the spectrum is seen. But, in the case of heat, our organs of sight are constituted so that we cannot discover its presence, and therefore fail to see the corresponding result. But it is now established beyond all doubt, that in the same manner that there are modifications of light giving rise to the various coloured rays, so, too, there are corresponding qualities of radiant heat. Moreover, it has been fully proved that, as stained glass and coloured

solutions exert an effect on white light, absorbing some rays and letting others pass, the same takes place also for heat. In the case we have already considered—of the imperfect diathermancy of glass—the true cause of the phenomenon is the colouration which the glass possesses as respects the rays of heat, and inasmuch as a substance may be perfectly transparent to one of these agents and not so to the other, so, also, a body may stop or absorb a given ray for the one, and a totally different one for the other. Glass allows all the rays of light to pass almost equally well, but it obstructs almost completely the blue rays of heat. The colouration of bodies, which has already been described as arising from absorption, may, therefore, be wholly different in the two cases; and as our organs do not permit us to see what it is in the case of heat, and we have to rely on indirect evidence, we speak of the imaginary or ideal colouration of bodies.

If heat, like light (as there are reasons for believing), arises in vibratory movements which are propagated through the ether, all the various phenomena here described can be readily accounted for. The undulations of heat must be reflected, refracted, inflected, undergo interference, polarisation, &c., as do the undulations of light, the mechanism being the same in both cases.

CHAPTER L.

CONDUCTION AND EXPANSION.

Good and Bad Conductors of Heat—Differences among the Metals—Conduction and Circulation in Liquids—Point of Application of Heat—Case of Gases—Expansion of Gases, Liquids, and Solids—Irregularity of Expansion in Liquids and Solids—Regularity of Gases.

When one end of a metallic bar is placed in the fire, after a certain time the other has its temperature elevated, and the heat is said to be conducted. It finds its way from particle to particle,—from those that are hot to those that are cold.

But if a piece of wood or of earthenware be submitted to the same trial, a very different result is obtained. The further end never becomes hot; proving, therefore, that some bodies are good and others bad conductors of heat.

The rapidity with which this conduction from particle to particle takes place, depends, among other things, upon their difference of temperature. Thus, when the bulb of a thermometer is plunged in a cup of hot water, for the first few moments its column runs up with rapidity; but as the thermometer comes nearer to the temperature of the water, the heat is transmitted to it more slowly.

Of the three classes of bodies, solids are the best conductors, liquids next, and gases worst of all. Of solids, the metals are the best, and among the metals may be mentioned gold, silver, copper. Among bad solid conductors we have charcoal, ashes, fibrous bodies—as cotton, silk wool, &c.

That the metals differ very much in this respect from one another, may be satisfactorily proved by taking a rod of copper, one of brass, and one of iron, *b c d*, Fig. 301, of equal length and diameter, and screwing them into a solid metallic ball, *a*, having placed on their further extremities at *b c d*, pieces of phosphorus, a very combustible body. Now, if a lamp be placed under the ball, it will be found that the heat traverses the metallic bars with very different degrees of facility, and the phosphorus takes fire in very different times; the first that inflames is that on the copper; then follows that on the brass, and, a long time after, that on the iron.

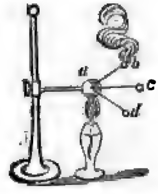


Fig. 301.

Liquids are, for the most part, very indifferent conductors of heat. This may be established, for example, in the case of water, by taking a glass jar, *a*, Fig. 302, nearly filled with that substance, and introducing into it the bulb of a delicate air-thermometer, *c*, so that a very short space intervenes between the top of the bulb and the surface of the liquid. If, now, some sulphuric ether be placed on that surface, and set on fire, it will be found that the thermometer remains motionless, and we therefore infer that the thin stratum intervening between the burning ether and the thermometer cuts off the passage of the heat. More delicate experiments have, however, proved that the liquid condition is not, in itself, a necessary obstruction. Even water does conduct to a certain extent; and quicksilver, which is equally a liquid, conducts very well.

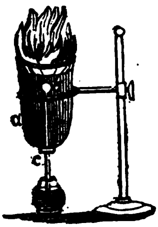


Fig. 302.

But experience assures us that, under common circumstances, heat is uniformly disseminated through liquids with rapidity. This, however, is due to the establishment of currents in their mass. We have seen how readily this class of bodies expands under an elevation of temperature, and this explains the nature of the passage of heat through them. When the source of heat is applied at the bottom of a vessel containing water, those particles which are in immediate contact with the bottom become warmed by the direct action of the fire, and they therefore expand. This expansion makes them lighter, and they rise through the stratum above, establishing a current up to the surface. Meantime their place is occupied by colder particles, which descend, and these in their turn become warm, to follow the course of the former. Circulation, therefore, takes place throughout the liquid mass, in consequence of the establishment of these currents; and all parts being successively brought in contact with the hot surface, are all equally heated. That these movements do take place, may be proved by putting into a flask of water, *a*, Fig. 303, a number of fragments of amber, adding a little glauber salt, to make the specific gravity of the liquid more nearly that of the amber, and then applying a lamp, currents are soon set up, and the amber, drifting in them, marks out their course in an instructive manner.

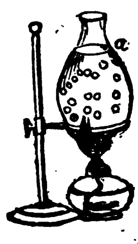


Fig. 303.

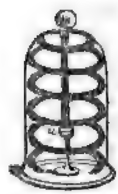


Fig. 304.

Such currents, however, wholly depend on the point of application of the heat. If the fire, instead of being applied at the bottom of the vessel, is applied at the top, as in Fig. 302, then the liquid can never be warmed. The cause of the movements of particles is their becoming lighter—they therefore float upward; but if they are already situated on the surface, of course no movement can take place.

With respect to gases, we observe the same peculiarity that we do with liquids. Strictly speaking, they are very bad conductors of heat; but, from the mobility of their parts, it is very easy to transfer heat readily through them, provided it is rightly applied. The experiment represented in Fig. 304, shows how easily circulation takes place in them. If a piece of burning sulphur be put in a cup, *a*, and a jar full of oxygen be inverted over it, the combustion goes on with rapidity, and the light smoke that rises marks out very well the path of the moving air. It rises directly upward from the burning mass, until it reaches the top of the jar, and then descends in circular wreaths to the bottom.

CHAPTER LI.

CAPACITY FOR HEAT AND LATENT HEAT.

Illustration of the Different Capacities of Bodies for Heat—Standards employed—Process by Melting—Process of Mixtures—Effect of Compression—Effect of Dilatation—Latent Heat—Caloric of Fluidity—Caloric of Elasticity—Artificial Cold.

By the phrase "capacity of bodies for heat," we allude to the fact that *different bodies require different degrees of heat to warm them equally.*

An experiment will serve to illustrate this important fact. If we take two bottles as precisely alike as we can obtain them, and, having filled one with water and the other with quicksilver, set them before the same fire, so as to receive equal quantities of heat in equal times, it will be found that the water requires a very much longer exposure, and therefore a larger quantity of heat, than the quicksilver, to raise its temperature up to the same point.

Or if we do the converse of this, and take the two bottles filled with their respective liquids, which, by having been immersed in a pan of boiling water, have both been brought to the same degree, and let them cool freely in the air, it will be found that the water requires much more time than the quicksilver to come down to the common temperatures. It contained more heat at the high temperature than did the quicksilver, and required more time to cool; it has, therefore, a greater capacity for heat—or, to use a loose expression, at the same temperature holds more of it.

There are several different ways by which the capacity of bodies for heat may be determined. Thus we may notice the times they require for warming, or those expended in cooling in a vacuum. Of course we cannot tell the absolute amount of heat which is contained in any substance whatever, and those determinations are hence relative—different bodies being compared

with a given one which is taken as a standard. For these purposes water is the substance selected for solids and liquids, and atmospheric air for gases and vapours.

There is reason to believe that the atoms of all simple substances have an equal capacity for heat; and that all compound bodies, composed of an equal number of single atoms combined in one and the same manner, have a capacity for heat which is inversely as their specific gravity.

When a solid substance passes into the liquid form, a large quantity of heat is rendered latent—that is to say, undiscoverable to the thermometer. Thus we may have ice at 32° and water at 32°, the one a solid and the other a liquid; and the precise reason of the physical difference between them is, that the water contains about 140°, which the ice does not—a quantity which is occupied in giving it the liquid state, and is insensible to the thermometer.

For this reason the transformation of a solid into a liquid is not an instantaneous phenomenon, but one requiring time. Ice must have its 140° of latent heat before it can turn into water. And, conversely, the solidification of a liquid is not instantaneous. It must have time to give out the latent heat to which its liquid state is due.

When a liquid passes into the form of a vapour, it is the presence of a large quantity of latent heat which gives to it all its peculiarities. Thus water, in turning into steam, absorbs nearly 1,000° of latent heat; and when that steam reverts into the liquid state the heat reappears.

To the caloric which is absorbed during fusion, the designation of *caloric of fluidity* is given—to that which gives their constitution to vapours the name of *caloric of elasticity*. And, as different bodies require, during these changes, different quantities of heat, there are furnished, in the works on chemistry, tables of the caloric of fluidity and caloric of elasticity of all the more common or important bodies. Of all known bodies water has the greatest capacity for heat; and in consequence of the great amount of latent heat it contains, it is one of the great reservoirs of caloric, both for natural and artificial purposes.

Hence, whenever a substance melts, it absorbs heat, and when it solidifies it gives out heat. When a substance vaporizes it absorbs heat, and when a vapour liquefies it evolves heat.

CHAPTER LII.

ON EVAPORATION AND BOILING.

Phenomena of Boiling—Effect of the Nature of the Vessel and the Pressure—Height of Mountains determined—Effect of Increased Pressure—Evaporation—Evaporation in Vacuo—Effect of Temperature on a Liquid in Vacuo—Explanation of Boiling—Nature of Vapours.

As the vaporization of liquids is connected with some of the most important mechanical applications, we shall proceed to consider it more minutely,

When water is placed in an open vessel on the fire the temperature of the whole mass ascends on account of the currents described in Chapter L. After a time, minute bubbles make their appearance on the sides of the vessel; these rise a little distance, and then disappear; but others soon take their places, and the water, being thrown into a rapid vibratory motion, emits a

singing sound. Immediately after this, the little bubbles make their way to the surface of the liquid, and are followed by others which are larger, and the phenomenon of boiling takes place. The heat has now reached 212°, and, it matters not how hot the fire may be, it never rises higher.

Different liquids have different boiling points, but for the same body, under similar circumstances, the point is nearly fixed. It is, indeed, in consequence of this that the boiling of water is taken as the upper fixed point of the thermometer.

In a polished vessel water does not boil until 214°; but, if a few grains of sand or other angular body is thrown in, the temperature sinks to 212°.

The absolute control which pressure exerts over the boiling point may be shown in many different striking ways. Thus, if a glass of warm water be put under the receiver of an air-pump and exhaustion made, the water enters into rapid ebullition, and continues boiling until its temperature goes down 67°. Water placed in a vacuum will, therefore, boil with the warmth of the hand.


Fig. 305.

Advantage has been taken of this fact to determine the height of accessible eminences. For, as we ascend in the air, the pressure necessarily becomes less; the superincumbent column of the atmosphere being shortened, the boiling point therefore declines. It has been ascertained, that if we ascend from the ground through 530 feet, the boiling point is lowered one degree; and formulas are given by which, from a knowledge of that point, in any instance the altitude may be calculated.

On the other hand, when the pressure on a liquid is increased, its boiling point ascends. This may be proved by taking a spherical boiler, *a*, properly supported over a spirit-lamp, there being in its top three openings; through *d* let a thermometer dip into some water which half fills the boiler; at *b* let there be a stop-cock which can be opened and shut at pleasure; and through a third opening between these, let a tube *c*, pass, dipping down nearly to the bottom of the boiler into some quicksilver which is beneath the water. Now let the water boil freely and the steam escape through *b*, the thermometer will mark 212°. Close the stop-cock so that the steam cannot get out, but, being confined in the boiler, exerts a pressure on the surface of the water, which is indicated by the rise of the mercury in the tube. As the column rises the boiling point rises, and if the instrument were adopted to show the results for high pressures, it might be proved that the boiling point—

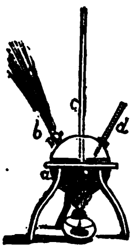


Fig. 306.

For 1	atmosphere is	212°	For 10	atmospheres is	358.8
2	"	250.5	15	"	392.8
3	"	275.2	20	"	418.5
4	"	293.7	40	"	666.5
5	"	307.5	50	"	690.7

Besides this escape of vapour from liquids during the act of boiling, the same is continually going on in a slow and motionless way, at lower temperatures. If some water be left in a shallow vessel exposed to the air, after a short time it all disappears. To this phenomenon the term evaporation is given.

At one time it was supposed that the atmospheric air acted on evaporating

bodies by an affinity for their vapours, in the same way that a sponge will soak up water. But the fallacy of this idea is proved by the fact that evaporation goes on more rapidly in vacuo, where no body whatever is present, than in the air. Thus, if into the torricellian vacuum of a barometer we pass a little ether, alcohol, or water, the moment they reach the void they instantly give forth vapour, and the mercurial column is depressed. With ether the depression is greatest, with alcohol less, and with water least of all. Now, when we consider the nature of the barometer, and the force which keeps the column of mercury suspended in it, it is very clear that this simple method affords us an easy means of knowing the elastic force of the vapours evolved from any of these substances: for the mercurial column is depressed through the operation of that elastic force. It is this which forces it downward, while the pressure of the air tends to force it upward.

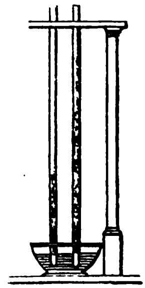


Fig. 307.

By thus introducing liquids into the barometric tube, we have the means of determining the elastic force of the vapours to which they give rise; and very simple experiments satisfy us that that elastic force depends upon the temperature. If we warm the tube, Fig. 307, by moving over it the flame of a spirit-lamp, the depression becomes greater; and if we surround it by means of warm water in a wider tube, so as to be able to ascertain with accuracy the temperature applied, we shall discover that as the heat rises the elastic force of the vapour increases, and that *the mercurial column is wholly depressed into the cistern as soon as the temperature has reached the boiling point of the liquid on which we are operating.*

Thus let A be a deep glass-jar, filled to the height *n* with mercury, and let *a b* be the barometric tube, into the vacuum of which, at *m*, the liquid under trial has been passed. Let a wide tube, *r c*, capable of holding hot water, be adapted, by means of a tight-fitting cork, at *s*, to the barometric tube. Now if, having observed the depression which the mercury exhibits at common temperatures, we fill the tube, *r c*, with hot water, a still greater depression is the immediate result. The temperature of the hot water, and therefore of the liquid in the barometer, can easily be determined by plunging a thermometer into the tube, *r c*.

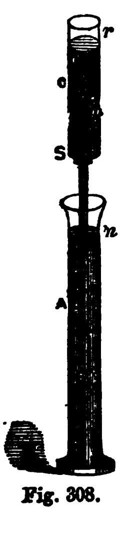


Fig. 308.

From such experiments, therefore, we draw this important conclusion:—*The elastic force of vapour rising from a liquid at its boiling point is equal to the pressure upon it.* If the ebullition be taking place in the open air, it is therefore equal to the pressure of the air.

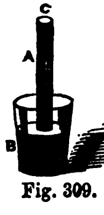


Fig. 309.

With respect to the nature of vapours, there is a good deal of popular misconception. Many persons suppose that they are naturally of a smoky or hazy aspect. But if we repeat the experiment represented in Fig. 309, and formerly described in Chapter VI., we shall find that so far as the vapour of ether is concerned, it is perfectly transparent, like atmospheric air, and by

proper examination the same may be verified for all other vapours. The true peculiarity is the facility with which this form of bodies assumes the liquid state. The moment the pressure of the air is restored, in this experiment, the ethereal vapour collapses into the liquid condition.

The same fact may be illustrated in another way. If we take a mattrass, *a*, Fig. 310, and fill the bulb and tube of it with water, and then introduce a little sulphuric ether into its upper part, the mouth dipping beneath some water contained in a jar, on heating the bulb by a spirit-lamp, the ether presently vaporizes. It may now be remarked—1st, that a vapour occupies a great deal more space than the liquid from which it comes; 2nd, that it has not a misty appearance; 3rd, that, under a reduction of temperature, it collapses into the liquid state—for, on removing the lamp, and suffering the bulb to cool, the vapour disappears.

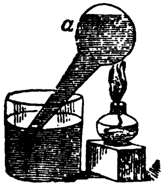


Fig. 310.

Either by diminution of temperature or increase of pressure, vapours may be condensed into the liquid state, and in this consists the chief distinction between them and gases.

CHAPTER LIII.

THE STEAM-ENGINE.

Elementary Steam Engine—Forms of this Machine—Description of the High-Pressure Engine—Principle of the Low-Pressure Engine, Description of the Double-Acting Engine—Estimate of Performance.

On the elastic force of steam, and on the rapidity with which it is condensed by application of cold, the construction of the different forms of steam-engine depends.

The instrument represented in Fig. 311, gives a clear idea of the elementary parts of a steam-engine. It consists of a cylindrical glass tube, B, terminating in a bulb, A. In the tube a piston moves up and down, air-tight, and a little water having been placed in the bulb, it is brought to the boiling point by the application of a lamp. As the steam forms, it presses the piston upward by reason of its elastic force, and, on dipping the bulb into cold water, the steam condenses and produces a partial vacuum, the piston being driven downward by the pressure of the air.

Fig. 311.

There are a great many modifications of the steam-engine. They may, however, for the most part, be reduced to two kinds: 1st, High-pressure engines; 2nd, Low-pressure engines.

The high-pressure engine, which is the simplest of the two forms, consists essentially of a very strong iron vessel or boiler, in which the steam is generated; a cylinder in which a steam-tight piston moves backward and forward; an arrangement of valves or cocks, so adjusted as alternately to admit the steam above

and below the piston, and also alternately to let it escape into the air*; and, lastly, a suitable contrivance by which the oscillations of the piston may be converted into other kinds of motion, suited to the work which the engine has to perform.


Fig. 312.

The action of the steam in one of these machines may be understood from the annexed diagram, Fig. 312. Let *f* be the cylinder, in which a solid piston, *e*, moves, steam-tight, and let us suppose the piston near to the bottom of the cylinder. The steam is now admitted through an aperture, *a*, and by its elastic force pushes the piston to the top of the cylinder. The movement of the piston-rod rearranges the openings into the cylinder, closing at a particular moment *a*, through which the steam has already come, and opening *b*; simultaneously, also, it opens *c* and closes *d*. Through *c*, from the boiler, a fresh supply of steam arrives, while it is shut off from *a*. This steam cannot escape through *d*, because that is closed—it therefore takes effect upon the piston and pushes it downward, all the vapour beneath escaping out into the air through *b*, which has been opened. This downward movement of the piston-rod rearranges all the valves, reversing the positions they have just had. It therefore opens *a*, shuts *b*; opens *d*, and shuts *c*. Steam now comes in from the boiler, through *a*, but cannot escape through *b*; it therefore pushes up the piston, driving out the steam, which is on its opposite side, through *d*, and in this way a reciprocating motion is produced.

The means of opening and shutting the apertures leading into the cylinder at the proper moment differ in different engines—sometimes cocks are used, and sometimes sliding-valves.

In this engine, therefore, the piston moves in both ways against the pressure of the air. The steam must be necessarily raised from water at a high boiling point, and hence these machines are much more liable to accident than the low-pressure engine, now to be described.

The rapid condensibility of steam—a principle intimately concerned in the action of the low-pressure engine—may be illustrated in the following manner:—Take a glass flask, *a*, Fig. 313, and adjust to its mouth a wide bent tube, *b*, both ends of which are open, having previously placed a quantity of water in the flask. Apply the flame of a spirit-lamp, and bring the water to the boiling point, continuing the ebullition until all the air is driven out of the flask, and nothing but steam remains. Then dip the open end of the tube into the jar, *c*, containing some cold water, and remove the lamp; the steam in the tube will at once begin to condense, through the influence of the cold water, which soon rises over the bent portion, and precipitates itself into the flask, often with so much violence as to break it to pieces.

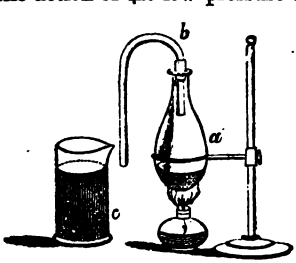


Fig. 313.

Of the low-pressure engine we have varieties—such as the single-acting and the double-acting engine. In the former, the piston is driven one way by means of steam acting against a vacuum, returning the other way by the counterpoising weight of the machinery. The machine, therefore, in reality, is only in action during half its motion.

The double-acting engine has the steam employed to produce both the ascent and descent of the piston into a vacuum on the opposite side. It therefore works continuously.

In expansive engines the supply of steam, instead of being continued during the entire ascent or descent of the piston, is cut off when the movement is one-half or one-third accomplished; the expansion of that steam driving the piston through the rest of the cylinder.

The following is a description of the double-acting engine. Fig. 314 represents the boiler and its appurtenances; Fig. 315 the engine.

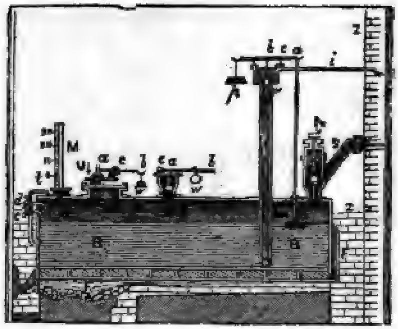


Fig. 314.

B B, Fig. 314, is the boiler, of a cylindrical shape, the fire, F F, is applied beneath; W W is the water-level, and S is occupied by steam. At *t t* there is a bent glass tube, open at both extremities, and so arranged that one end is in the steam space, and the other in the water; it serves to show the level of the water in the boiler. In some cases, two cocks, *c* and *d*, are inserted in the boiler, one entering into the steam part and one beneath the water. On opening them, if the water is at its proper level, steam will escape from the upper, and water from the under one. If there is too much water, it escapes from both. The boiler is continually replenished by the *feed-pipe*, the nature of which has been explained in Chapter XIV. At M there is a barometer-gauge, to show the elastic force of the steam; at *e a b* a safety-valve, with its weight, *w*; this opens upward, so that, should the elastic force in the interior of the boiler become too great, the valve opens, and the steam escapes. On the contrary, to prevent the boiler being crushed in by the atmospheric pressure, when the expansive force of the steam happens to decline, there is a second valve at U, with its lever, *a c b*, and weight, *w*, which opens inward, that when the external pressure exceeds the weight the air may find access to the inside of the boiler. And, as it is necessary from time to time to clear the boiler from the incrustations or deposits of salt and other impurities, there is an opening, as at L, through which access can be had. This, of course, is, at other times, securely closed. Lastly, from the boiler there passes the steam-pipe, *s*, which is opened by the valve at N.

Fig. 315 represents the engine, properly speaking. At *z z* it should be imagined as being continuous with *z z* of Fig. 314; so that in both figures the tubes *i i* and *s s* are continuous. In both, *s* is the tube along which the steam from the boiler is delivered to the cylinder—passing through the *four-way* cock, *a*, either down through *a* or up through *b*, into the cylinder C, in which the piston, P, moves. Admission for the steam, above or below the piston, is regulated by a system of levers, *y y*, the necessary motion being communicated by the machine itself. The piston-rod, E, is connected with the beam, B F, working on the fulcrum, A. The connecting-rod is F R. At R it is attached to the crank by a pivot, H H H, being the fly-*wheel, the* revolution of which gives uniformity to the motion. The steam,

after elevating or depressing the piston, passes through the eduction-pipe, *f f*, into the condenser, J, which is immersed in a cistern, L, of cold water. In this it is condensed into water by a jet which passes through the injection cock. The resulting warm water is pumped out by the air-pump, O, into the hot well, W; thence it is carried, by the hot-water pump, *b*, along

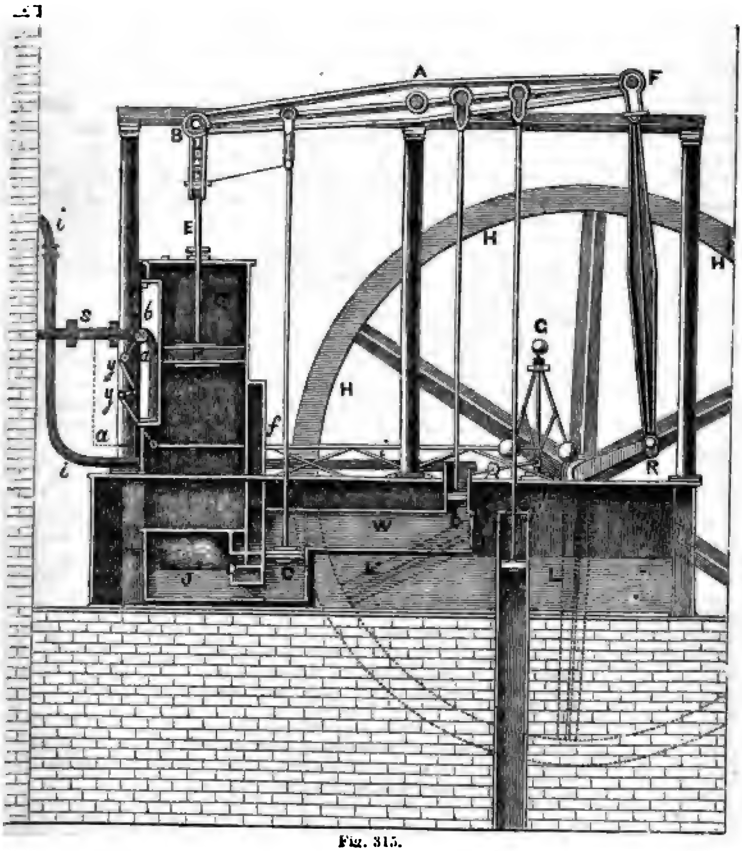


Fig. 315.

the feed-pipe, *i i*, into the boiler. The cold-water pump, S, supplies the reservoir with cold water. All the pumps are worked by the beam of the engine. The supply of steam is regulated by the governor, G, so as to be kept constant.

The performance of steam-engines is commonly estimated by horse-power. The value of the power of one horse is a force sufficient to raise 33,000 pounds one foot high in one minute.

We will now explain how motion is communicated to the fly-wheel, and thence to machinery. This we can explain without a diagram. You have, we dare say, often watched a knife-grinder, and perhaps examined his grinding apparatus. You observe that he puts his foot upon a treadle, from which a strap passes to a crooked part of the axis of the fly-wheel. This part is called a crank. Now, there is just such a crank upon the axis of the fly-wheel of a steam-engine. If, then, you imagine a rod, or strap, to proceed from one end of the beam to this crank, you will at once see that it will revolve as the beam goes up and down; in fact, the beam and rod only supply the place of the knife-grinder's treadle and strap. This fly-wheel is of great use; it is, as it were, a reservoir of work, for it soon attains a steady equal motion; and if it should happen that at certain times there is less work to be done, the extra power of the engine is accumulated in, and taken up by, the fly-wheel; and the momentum it acquires also prevents the engine from stopping suddenly, and it is thus calculated to give an uniform motion to the machinery connected with it.

The giant power, from earth's remotest caves,
Lifts with strong arm her dark reluctant waves;
Each cavern'd rock, and hidden den explores,
Drags her dark coals, and digs her shining ores:
Next in close cells of ribbed oak confined,
Gale after gale, he crowds the struggling wind;
The imprison'd storms through brazen nostrils roar,
Fan the white flame, and fuse the sparkling ore.
Here, high in air, the rising stream he pours,
To clay-built cisterns, or to lead-lined towers;
Fresh through a thousand pipes the wave distils,
And thirsty cities drink th' exuberant rills:
There the vast millstone, with inebriate whirl,
On trembling floors his forceful fingers twirl,
Whose flinty teeth the golden harvests grind,
Feast without blood, and nourish human kind.
Now his hard hands on Mona's rifted crest,
Bosom'd in rock her azure ores arrest;
With iron lips his rapid rollers seize
The lengthening bars, in thin expansion squeeze;
Descending screws, with ponderous fly-wheels wound
The tawny plates, the new medallions round;
Hard dies of steel the capeous circles cramp,
And with quick fall his massy hammers stamp,
The harp, the lily, and the lion join,
And George and Britain guard the sterling coin.
Soon shall thy arm, unconquered steam! afar
Drag the slow barge, or drive the rapid car;
Or on wide-waving wings, expanded bear,
The flying chariot through the fields of air.

PART II.

POPULAR GEOLOGY.

POPULAR GEOLOGY.

INTRODUCTORY CHAPTER.

THE MATERIAL ORIGIN OF THE GLOBE.

1. *The name* Geology is derived from two Greek words, *ge*, signifying the earth; and *logos*, a discourse; and which, together, may be translated as reasoning about the structure of the earth, or simply the science of the earth.

2. *The objects* of Geology are to produce a true history of the origin and structure of the globe; of the changes which it has undergone; of the various tribes of plants and animals which have at different periods occupied its surface; and, lastly, to reason from the known state of things in the past to the probable state of things in the future.

3. *Cosmogony, necessarily a part of Geology.*—As to the origin of the earth, many Geologists appear to think that, as the utmost efforts of man's mind can only enable him to speculate upon this vast mystery, it should be altogether dismissed from the region of Geological science. Hatton says, Geology is in nowise concerned with questions as to the origin of things; and Lyell, that Geology differs as widely from Cosmogony,* as speculations concerning the mode of the first creation of man differ from history. Now, these gentlemen would be the last to say, that between the material mode of originating the world, and its existing structure, there is an impassable barrier; or, in other words, that there is no *cause* in the first bearing a distinct relation to *effects* in the second. They both believe just the contrary. Geology, therefore, has, we think, rightly concerned itself with the origin of the globe, and must continue to do so. But let us not be mistaken. Crude speculations on such a theme are worse than useless; they are, so to speak, irreverent. Men should come to such a subject with something of the spirit that imbued those who were privileged to enter the Holy of Holies in the ancient Jewish temples. The high-priests of knowledge alone should walk here.

4. *Laplace's Theory.*—The philosopher whose speculations on the origin of the world have stood without injury the test of time, and an unceasing comparison with all the known phenomena of the solar system, is the French astronomer and mathematician, Laplace. The following theory is founded upon his views. Vast extensions of luminous and heated matter exist in space. In one of these a nucleus is established and becomes a centre of aggregation to the neighbouring particles. As they flow on in varying directions, opposing currents are formed, which meet, and cause a rotatory motion

* The scientific word, especially expressive of speculations on the origin and creation of the world.

to take place; just as we may see, in the waters of a running stream, little bubbles appear, go round and round, strike against each other, then mingle perhaps into one, and still continue to rotate. As the nucleus—or Sun, for it is that of which we speak—increases in size, so it increases in rapidity; and should condensation take place through the loss of heat, arising from a difference of temperature between the heated nebulous matter and the colder surrounding space, that would also accelerate speed. At last the centrifugal, or flying-off force, overcomes the agglomerating or centripetal force, and mass after mass is thrown off in the form of rings or zones. If these happen to be of uniform constitution, they preserve their shape, as in the instance of the rings of Saturn, thrown off originally in the same way from the planet, as the planet itself was thrown off from the primary body, the Sun. If the zones are *not* thus uniform in their constitution, they break up into one or more masses, having the same degree of speed and the same orbital line of progress as the parent zone possessed before its separation from the main body, and rotating in consequence of the excess of speed existing in the outer as compared with the inner portion of the zone. Thus, it is presumed, our world and the other planetary bodies was formed from the sun; and thus, by a repetition of the same process, were the moon and other planetary satellites formed from the planets.

5. *Original Dimensions of the Sun.*—If this view becorrect, the original dimensions of the Sun in its undivided state were identical with the dimensions of our entire solar system; and the subsequent history of its condensation is strikingly told by the several orbits of the planets; each of these marking the Sun's dimensions at the time the planet was dismissed into space, to lead a comparatively independent existence.

6. *Original Dimensions of the Earth.*—Our globe, again, must have extended to the line now traced by its satellite, the moon; must have been then 482,000 miles in diameter, instead of nearly 8,000 miles, as at present; and must have taken twenty-nine days and a half to rotate on its own axis, instead of twenty-four hours.

7. *Common Direction of the Planetary Bodies, evidence of a common origin.*—Of course, it is indispensable to such a theory, that the planets and their satellites should all show their original unitary movement in their present individual movements. And this they do. The planets have one common direction round the Sun; the satellites move in the same direction, whilst also encircling their respective planets: and both planet and satellites, while revolving each on its own axis, make that revolution also in the same general direction, viz., from west to east, which is the Sun's own movement round its axis.

8. *The Origin of the Planetary Bodies also illustrated in their respective densities.*—The planets and satellites should also, to be in accordance with this theory, possess varying degrees of density. The heavier portions of the parent body must have been the most central; the lighter, those nearest the extremity, and therefore the first to be thrown off. This also is essentially the truth. The planets nearest the Sun are the most dense, the farthest from it the least so; the exceptions being only such as may be ascribed to some of the lesser influences that may have modified the general law. The order of the chief planets, as regards their different degrees of proximity to the Sun, is—Mercury, Venus, Earth, Mars, Jupiter, Saturn, Uranus: now, Mercury, the planet nearest the Sun, is almost three times as dense as the Earth;

whilst the earth itself is nearly four times as dense as Uranus, the body farthest from the Sun of those we have named.

9. *Chemical proof of Laplace's Theory, down from the Earth's Elements.*—Chemical analysis of the component parts of the earth's body leads us, by a more exact and trustworthy route, to corresponding conclusions. All known substances, however varying in apparent origin, structure, qualities, and uses—from the humblest pebble beneath our feet, up to the highest human organization—may be resolved into about fifty-five elementary substances; and which substances, it is presumed, are not themselves compound; that is to say, are not capable of further division. Forty of these are metallic bodies, twelve non-metallic, and three intermediate between the two. Turning from the consideration of the foregoing theory of the earth's material origin, to these elements of the earth itself, one naturally asks—Can these bodies have ever been in the state of heated vapour, or "fire-mist," as it has been called? The answer is easy and satisfactory. Four of the non-metallic bodies exist permanently gaseous: these are oxygen, hydrogen, nitrogen, and chlorine. One-half the solid matter of the globe is estimated to consist of oxygen. It forms a fifth of the atmosphere; eight-ninths of water; and a large proportion of every kind of rock. When freed from its connection with solid bodies, it expands to two thousand times its former bulk. What happens to freed oxygen would occur with chlorine and other substances similarly disengaged. Look at water, also—forming ice at a temperature lower than 32°—becoming steam at 212°. All these facts point to the conclusion, that every one of the substances of the globe might be converted, under certain circumstances, into gas; and of course, therefore, tend greatly to confirm the hypothesis, that from gas they all came.

10. *Heat the Cause of Original Expansion.*—Condensation and expansion are, thus, the two opposite processes which the world exhibits, when its present is compared with its original condition. Cold is connected with the one, heat with the other. Was heat, then, the influence that originally kept in a state of vapour all the varying substances that comprise ourselves, and everything around us that we can touch or see? Most probably it was. On descending into the bowels of the earth, as by means of mines and other deep excavations, we find that as soon as we have passed below the regions affected by the sun and other external influences, there is a constant increase of heat as we descend lower and lower. Miners, as is well known, are often obliged to work absolutely naked. It has been calculated that, for every fifteen or sixteen yards of descent, the heat increases one degree of Fahrenheit. Volcanos, and hot springs of water, seem also to suggest subterranean heat as their origin.

11. *Density of the Earth only to be explained by the hypothesis of Central Heat.*—The known degree of density of the earth is such as can only be explained on the hypothesis of some interior force lessening the effects of the concentration of such a mass of solid matter. The surface rocks are only two and a half times as heavy as water; and although the average density of the globe is more than five times as heavy as water, how small is that proportion still to what must have been the weight of the whole earth were there no antagonistic influences! Water at the depth of 362 miles below the surface acquires by compression the density of quicksilver; whilst marble at

the centre of the earth would be one hundred and nineteen times as dense as it is on the surface. Heat is, probably, the antagonistic force.

12. *Formation of the Igneous Rocks also supports Laplace's Theory.*—In descending below all these rocks, whose formation and contents evidently point to periods subsequent to the original creation of the globe, we find underlying the whole, as a kind of natural and universal floor, granite and similar rocks, known as igneous rocks, because they appear to have been produced in their present state by the action of heat strong enough to have kept their constituents in a state of fusion, and which on cooling crystallized. This great fact seems further to corroborate the preceding theory.

13. *So also does the Form of the Earth.*—Lastly, the figure of the globe is known to be precisely that which would result from the revolution on its axis of a body in a fluid or semi-fluid state; and which, as heat passed off by refrigeration from the surface, would consolidate and remain permanently in the shape in which it now exists—that of a globe a little flattened at the poles.

14. *Present State of the Interior of the Earth.*—Whether the interior be now entirely solid, or partially fluid, is a matter unsettled even as a theoretical question. The answer depends upon a very difficult problem. Which exerts the greatest power—the condensing pressure of the superincumbent mass at or near the centre, or the expanding force of the heat?

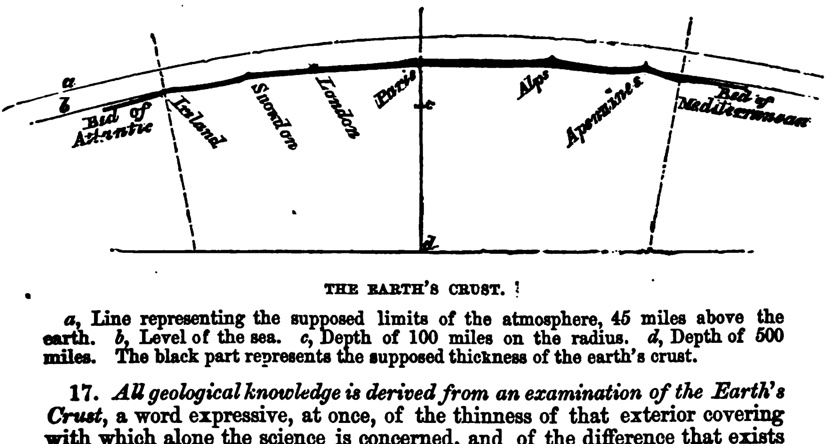
15. *Other Theories as to the Cause of Heat in the Interior.*—We must not omit to state, that there are other views maintained as to the cause of interior heat. Some suppose that it is heated by the access of water or other oxygenized bodies, to chemical substances in the interior—an hypothesis that has been also generally applied to the explanation of volcanic eruptions. Another hypothesis is, that electricity may be the cause of the intense heat; and some who support this theory object to the one we have explained as the most credible, on the ground of certain experiments which have been made, and which seem to show that substances cannot, under ordinary circumstances, be maintained at a high temperature while in contact with others of a lower one. Presuming this to be correct, it only seems to show that special combinations of chemical force must be at work, to keep up this perpetual heat. Surely no student of chemistry will find it difficult to realize the probability, not to say possibility, of this.

16. *Liebig's Chemical Views in support of Laplace's Theory.*—We conclude this introductory chapter by a passage from the latest work of our latest chemical philosopher, Liebig, which supports incidentally, but strongly, the theory we have endeavoured to explain and illustrate. "Expansion of heat," he says, "implies that the atoms of which a substance is composed separate to a certain distance from each other. Now, since a certain contiguity of atoms is a necessary condition for the action of chemical affinity, it is obvious that by the mere effect of heat a number of chemical combinations must be resolved into their constituents; and this, indeed, always in cases where the influence of heat causes the distance between the ultimate particles to extend beyond the sphere of chemical attraction. This necessarily causes a separation. When the heat decreases, the atoms again approach each other, and at a certain point of proximity, combination again ensues. We may imagine that at a temperature immeasurably high to us, substances can exist in one and the same place without combining, although

they may possess the very strongest affinity for each other; and that, because this high temperature neutralizes their affinity, opposes an insurmountable resistance to its operation. So, undoubtedly, the constituents of the earth, when they possessed an exceedingly high temperature, were arranged in quite a different manner from that in which we find them at present. Nay, it is not impossible that they should have floated through each other as in a chaos, and that this chaos formed itself into our present minerals and rocks only when this temperature was greatly lowered. Let us suppose all the elements composing the earth, by the influence of a great heat, to be brought into the same state in which oxygen and hydrogen gas exist at the common temperature of the atmosphere, the earth would be an enormous ball of nothing but gases, which everywhere would uniformly mix without entering into combination, just as in the case with oxygen and hydrogen, despite their exceedingly great affinity."

CHAPTER II.

THE MEANS OF GEOLOGICAL STUDY—STRATIFICATION.



THE EARTH'S CRUST.

a, Line representing the supposed limits of the atmosphere, 45 miles above the earth. *b*, Level of the sea. *c*, Depth of 100 miles on the radius. *d*, Depth of 500 miles. The black part represents the supposed thickness of the earth's crust.

17. *All geological knowledge is derived from an examination of the Earth's Crust*, a word expressive, at once, of the thinness of that exterior covering with which alone the science is concerned, and of the difference that exists between the covering and the profound unknown abyss that lies beneath.

18. *Apparent insufficiency, but real Value of the Crust.*—When, in looking at the black line in the above diagram, which includes a depth of fifteen miles, or nearly three times the actual depth to which our observations have really been able to extend, and comparing it with the depth of the earth from the surface to the centre (of which depth only an eighth part is there shown) we are told, "Within that black line are confined all our means of geological investigation," we may naturally feel disappointed at the apparent inade-

quacy of the materials afforded. But the case is not so. And mainly for this broad reason—that as the crust *does* show us, under a variety of circumstances, the lowest of all rock formations—the granitic or crystalline—below which no signs of periodical formation or of life, in connection with even the remotest eras, can be found; it is therefore probable that we have really within our grasp a complete series of remains of the varying and mighty phenomena that have marked the material history of our globe; and th t, even if there be deficiencies, through the changes that have taken place, under the operation of those natural influences, still ever at work around us, it is all but certain that these deficiencies could not be supplied by deeper descents into the solid substance beneath. But the fact that we can, under certain circumstances, look upon this universal floor of all things, as when, for instance, it is protruded to or above the surface, by expansive interior forces, does not at first glance suggest how it is that we are enabled to trace, step by step, the nature of the various masses that generally lie above it. Although the loftiest mountains rise to nearly the height of five miles, they are mainly of granite, or other igneous formations, and leave generally the lower formations above them as difficult to examine to any depth, as in their natural position. The deepest mines, again, only descend about the third of a mile, and therefore can but exhibit portions of the contents of the crust. How is it, then, that Geology, with such seemingly limited opportunities for study, has risen to the rank of a science? We may answer by the enunciation of the following propositions:—

19. *Opportunities for studying the Crust.*—First. although we cannot descend into the bowels of the earth to such depths as might enable us to trace, in their normal aspect, the nature of all the materials that overlie the granite floor, the materials themselves have been in innumerable cases forced up to the surface, without, for the most part, losing the distinctive features of their original position. Again, in all parts of the world are found deep natural excavations, the edges of which tell their history eloquently to those who know how to understand such geological effects. River banks and the shores of the sea often exhibit the same opportunities. Lastly; when a great depth of the earth's crust has been forced upwards in an inclined position, it is obvious that what was the lowest portion may become not very materially lower in its new position than that which was originally the highest, the latter probably being depressed by the same operation. Let us illustrate this by a familiar image:—Take a pack of cards; hold them so firmly together that they remain in juxtaposition, but so loosely, that when the edges are pressed upon the table in an inclined position, they will form themselves into a line agreeing with the angle of that inclination, slightly overtopping each other, like a series of minute steps. Let these steps be visible on the left, rising upwards, and, of course, concealed on the right by the overtopping edges. Then hold the pack horizontally, but with the right edge a little depressed, and you will have an exact representation of the state in which we often find a number of layers of the earth's substance. If, now, excavations are made—as in mining, or in boring for water—at different portions of that group of layers, those made at the end, where lies the original surface, will penetrate through, possibly, the first three layers, as Nos. 1, 2, 3; the next may have No. 2 at the top, or surface, and therefore may go through 2, 3, 4; the next through *3, 4, 5*; and so on, until a series of excavations, thus made, under favour-

able circumstances, may show us in complete detail the character of every layer, and their successional relation to each other.

20.—*The Crust is found disposed in layers or strata.*—By these and similar means we arrive at the discovery that all the rocks, soils, minerals, &c., that constitute the substance of the earth's crust, are arranged in distinct layers or beds, spread out, or strewed one above another, hence called *strata*.

21. *These strata always occupy determinate relative positions.*—Strata, when lying in their natural undisturbed positions, invariably occupy a certain regular determinate order, so that, for instance, if groups of six different strata or formations be found in different parts of the world, those six will always be discovered in the same successional order; or, in other words, that while certain strata requisite to form a complete group may be missing from the group, those that are found together will always exhibit, if undisturbed by what we may call accident, the same relative order of super-imposition.

22. *And contain distinct animal and vegetable remains or fossils.*—Whilst strata are thus distinguished from each other, we find that each stratum contains a distinct series of remains of vegetable and animal life, showing, in fact, what were the living inhabitants of the globe at the time each layer was deposited. It is not meant to say that all the constituent individual species of the Flora and Fauna of any one particular formation or strata are entirely different from those of every other, but simply that, taken as a whole, each formation differs from the one above or below it.

23. *The chief instruments of geological investigation recapitulated.*—These, then, are the chief instruments of geological investigation, and it will be seen that they are sufficiently powerful to task all the efforts of science to make the best use of them. To recapitulate: The earth's crust, though thi as compared with the substance of the globe, contains probably all the essential materials that can be required for study; and that crust is, under one form or another, available through its entire depth for our examination. We find that crust formed of a series of layers, dispersed in a regular determinate order; each evidently having been the surface of the globe for a time probably of incalculable extent, and each having its own peculiar system of organic life.

24. *Scientific and popular notions of the crust directly opposed.*—Nothing, therefore, can be more opposed than these facts to the popular notions that have so long existed, which look upon the superficial substance of the earth as a confused agglomeration of various soils, and rocks, and minerals, simultaneously brought into existence by one act of creation.

25. *Geological meaning of the word Rock.*—All the various substances which compose the earth's crust, as sand, gravel, clay, peat, rocks of all kinds, popularly so called, coal, slate, minerals, &c., are summed up by geologists into the one word rocks; and this without reference to the fact whether they be soft or stony.

26. *Chief Geological division of Rocks.*—These rocks are divided into two great classes:—

I. Igneous, or unstratified rocks.
II. Aqueous, or stratified rocks.

27. *Igneous Rocks, unstratified.*—Igneous rocks, as we have already had occasion to show, are those resulting from the operation of heat, and which

crystallize in the process of cooling. They are, of course, unstratified, and destitute of all organic remains. Granite is the great exemplar.

28. *Aqueous Rocks, stratified.*—Aqueous rocks include all those that extend upward from the underlying granite or igneous rocks; and are so called because they have evidently all been deposited as sediment from water, and mostly in the shape of sand, clay, &c., which were subsequently hardened and in various other ways affected by subterranean heat, and also by the superincumbent pressure of other formations that were gradually deposited upon them.

29. *Modes of deposition, &c., of Aqueous Rocks.*—Aqueous rocks deposited in seas can be distinguished from those deposited in the waters of lakes and estuaries by the kinds of fossils contained in them; some, of course, obviously being inhabitants of salt, others only of fresh water. We can also learn much of the climate that prevailed during any particular formation by studying the character of the fossil vegetation it has left behind. Plants of a kind that only now exist in a tropical climate doubtless had such a climate then.

30. *Difference of Structure of Aqueous Rocks.*—The differences of structure existing among different strata, as, for instance, between the fine grain and thin laminæ of slate, and the coarse conglomerate of gravel; or again, between the soft, white, incombustible substance of chalk, and the hard, black, highly inflammable coal, imply great difference in the circumstances under which such varying materials were deposited, independent of their common watery origin. These circumstances, as far as known, we shall have to investigate at greater length when we consider the several chief formations in detail. We shall, therefore, for the present, merely show, generally, their natural origin.

31. *Substance of Aqueous Rocks—whence obtained.*—Starting from that granitic crust which, with vast and profound oceans, seems to have formed the infant condition of the earth, we can readily perceive that each group of strata has been formed from its predecessors by the operation of laws still at work. Thus the atmosphere, by its mechanical and chemical powers, wears down the rocks; the particles are carried by rivers to the sea, then gradually deposited, hardened and altered by heat and pressure, and at last assume that state in which, when time and physical revolutions have done their work, they may each become to man one of the leaves of the great book of geological history. We need, at present, give only a single illustration of the fact, that the later rocks are thus formed from the earlier. The gneiss rocks, found immediately above the granite, are composed of materials that every one can see at a glance are but slightly altered from granite.

32. *Accidental Positions of Strata.*—The positions of rocks are, in their normal state, nearly horizontal, though the circumstances under which we generally see them, as already explained, cause them to be greatly modified. Earthquakes and volcanoes have thrown them into a thousand different forms—grand, beautiful, and fantastic. Their lesser characteristics of position are geologically resolved into the following technical divisions:—Fractures or disruptions, overlying strata, false or pseudo-interstratification, veins, faults, dykes, slips, hitches, &c., &c.

33. *Fractures* may be single—that is, unaccompanied with discharges of fluid, or upheaving of solid igneous matter beyond the surface. Thus ex-

pansive forces from below crack the solid earth above, obtain vent, and leave behind them vast fissures. Or fractures may arise from the sudden uplifting of an enormous bulk of solid rock, which, penetrating the crust, rises upward into the stature of a vast mountain, or perhaps even into a widely-extending range of mountains.

34. *Overlying Strata.*—Or the mass, so driven up and vomited forth, may be in a state of fusion, and, accordingly, spread itself over the neighbouring surface strata, and hence be called overlying.

35. *False, or Interstratification.*—Or, raised upwards less powerfully, the intruding granite may simply force its way between the superincumbent strata, and there remain as an example of false, or interstratification.

36. *Dykes.*—Or, still more weakly impelled, it may find its way into some small existing fissure, and so form a dyke; and which does not always run merely in a vertical or inclined position towards the surface, but sometimes extends horizontally. Thus we sometimes see dykes of granite extending along the ground like an artificially raised wall, the softer strata in which they were imbedded having wasted away.

37. *Veins.*—Or, lastly, the expanding force may drive the igneous—and in this case, evidently fused rock—into a great number of branching and minute crevices, to which geologists give the name of veins.

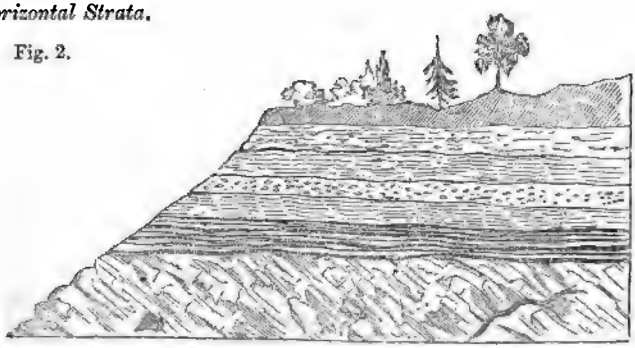
38. *Faults.*—By the word fault is meant that some portions of rocks or strata, having been lifted and disruptured, the edges, in falling, have fallen into positions different from those they originally occupied as regards each other, even though again touching. Fig. 3 affords an example.

39. *Slips.*—A slip is a minor fault, and expresses the fact, that while an upheaved and divided body falls back again, each part with the same horizontal position as it before occupied, one side falls lower than the other.

THE FORMS OF STRATA may be all comprised within the following:—

40. *Horizontal Strata.*

Fig. 2.

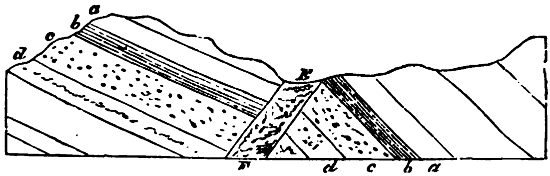


This diagram is intended to show how different strata are found lying horizontally upon each other, and must not be supposed to represent any particular rocks.

41. (*Fig.* 3.) Inclined strata, with fault in the centre, filled with rubbish. Strata in this position must have been raised and dislocated by expansive

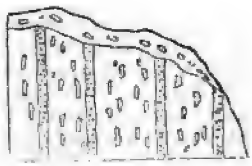
Fig. 3.

Vertical Strata and Fault.



forces from beneath. The angle which inclined strata present to the horizon is called the *dip*, or angle of inclination.

42. (*Fig.* 4.) *Vertical Strata.*—This engraving presents a good example of a very interesting kind of stratification. "Vertical strata afford," says Sir Charles Lyell, from whom we borrow this and one or two other illustrations, "the most unequivocal evidences of a change in the original position. . . . We find in Scotland, in the northern skirts of the Grampians, beds of pudding stone, alternating with the layers of fine sand, all placed vertically to the horizon. When Saussure first observed certain conglomerates in a similar position in the Swiss Alps, he remarked that the pebbles, being for the most part of an oval shape, had their longer axes parallel to the planes of their stratification. (See Fig. 4.) From this he inferred that such strata must, at first, have been horizontal, such oval pebble having originally settled at the bottom of the water, with its flatter side parallel to the longer, for the same reason that an egg will not stand on either end if unsupported."



Example of Vertical Conglomerate and Sandstone from the Swiss Alps.—VERTICAL STRATA.

Fig. 4.

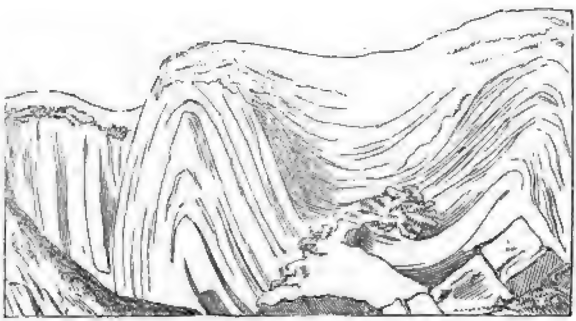


Fig. 5.

43. (*Fig.* 5.) *Curved or Contorted Strata of Slate near St. Ann's Head, Berwickshire.*—Sir James Hall explains very happily the mode in which these strata were formed. He placed a set of layers of clay under a weight, and then pressed their opposite ends together with such violence as to com-

pel them to approach. On the removal of the weight, the layers of clay were found curved after the manner shown in the above engraving.

44. *Unconformable Strata.*—Our example is chosen from the junction of the Old red sandstone and Silurian schist, at the Siccar Point, near St. Ann's Head, Berwickshire. Its meaning is obvious; while the lower stratum is

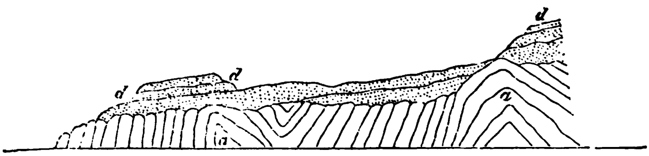


Fig. 6.—UNCONFORMABLE STRATA.

inclined or vertical, the upper is horizontal: such combinations are called unconformable. The explanation is easy. The inclined stratum was raised and turned out of its natural position, and then the next was naturally formed horizontally upon it.

45. *Other Strata* are also distinguished by special names, as, *tilted*, when suddenly bent up by subterranean force; *saddle-back*, or anticlinal, when dipping from a common ridge in two opposite directions; and *trough*, or basin-like, or synclinal, when exhibiting the reverse of the last position, or dipping from opposite directions to a common point. When a stratum comes to the surface and appears it is said to *crop out.*

CHAPTER III.

THE MEANS OF GEOLOGICAL STUDY—FOSSILS.

Meaning of Fossilization.—By fossilization we mean the study of those relics of vegetables and animals which are found in stratified rocks, and which only cease to appear as we delve down towards the granite.

State of Preservation in which Fossils are found.—Fossils are found in varying states of preservation, of modification, and of almost entire change. They are often broken—a fact that may be ascribed to the turbulence of the actions which accompanied their original inhumation; and often worn, by long rolling against hard surrounding substances. Certain portions, again, of a fossil, will decay, while the rest remains uninjured. The pieces of bivalve shells are thus often discovered apart, through the decay of the hinge ligaments. Mechanical compression produces peculiar effects, as may be witnessed in the compressed ammonites found at Watchet and other places; in the goniates and pectens of Bradford, in Yorkshire; and in the fishes and ichthyosauri of Charmouth. Perhaps the most interesting cases of fossil compressions are found in the shales and gritstone that overlie coal, where the large cylindrical stems of Sigillaria and Lepidodendron are found as flat as paper, when buried between the laminæ of shale, depressed elliptically when

lying across the grits, and retaining their original cylindrical figure when standing erect in the rocks.

Chemistry of Fossil Plants.—The chemical phenomena exhibited by fossils are of the greatest importance. We may illustrate these by a brief review of the chief stages of alteration that plants are found to exhibit in passing from their original and living to a fossil state.

1. They are found but little altered, as in the brown coal formations of the Rhine; and in a particular case at Gristhorpe, near Scarborough, among the oolites, where a plant, called by Lindley the *Solenites Murrayana*, is found flexible, elastic, and with its tissues quite distinct.

2. The plants have become carbonized or bituminized, a very common conversion in the clays of every geological era, and plentifully in what are called the coal formations.

3. The substance of the original plants passes entirely away, by the combination of its elements with the surrounding parts, so that a mere blank remains; but an eloquent blank, for its shape reveals the sort of being that had once occupied the now desolate space. The coarse gritstone near Leeds affords examples of this state.

4. Lastly, the cells of the vegetable structure become filled with extraneous matter, as carbonate of lime—hence the pyrites of Lepidodendron Harcourtii in the fruits of Sheppey; or with silica, and hence the flinty or silicified wood of Woburn.

Chemistry of Fossil Animals.—These exhibit analogous changes. Thus we have—

1. Such relics as the scales of fishes, coverings of shell-fish, and bones of vertebrated animals, and which are often found but slightly changed, in some cases even retaining their gelatinous portions.

2. The next step shows to us entire shells, corals, and echinodermata, composed of carbonate of lime and gelatine; the latter substance, in some cases, still partly preserved. From this state we pass, by almost insensible gradations, to that where the organized substances are entirely lost, as in the oolites especially; and there is either left a vacancy, on the sides of which the lost shell has sculptured itself, as it were, for a future memorial before its disappearance; or,—

3. There is a mass of mere stony matter, which also tells the story of what has taken place, by exhibiting on its surface the exact representation of the animal whose being it has absorbed into its own. It is curious to note, that while it was by the absorption of carbonate of lime the vacancies above referred to were formed, it is by carbonate of lime, in many cases, entering in a state of solution, that we find, in other instances, what would have been vacancies are filled up. Silica or flint, and sometimes (but unfrequently) iron pyrites, fill those vacancies.

Relations of particular Rocks and Fossils.—The relations between rocks and the particular fossils they respectively contain may be illustrated by a few examples. In the green sand formations most of the shells and spongiadæ are silicious. In the oolites the fossils are chiefly calcareous, lime being one of the commonest of these transforming agencies. In the coal formations the fossils are more or less bituminous. Certain tribes—as the belemnites and ostracea—retain their fibrous or lamellar structure in all sorts of rocks.

Local Distribution of Fossils.—Fossils are found on the tops of the loftiest mountains of the Alps and Pyrenees, showing that what was the original

surface of the crust at the time the mountains had been upheaved was carried upwards with them: fossil plants are found at the bottom of our deepest mines. Of course, fossils, generally, are most plentiful on or near the earth's surface, because the formations there are chiefly of a later origin than the stratified rocks which were uplifted in mountain chains. At the depth of a few thousand yards they cease altogether to appear, with the cessation of the appearance of the stratified rocks, in which alone they are found. There are many interesting peculiarities connected with the local distribution of fossils. Some of the ancient limestones about Torquay, in Devon, are composed almost entirely of the remains of animals, chiefly Polyparia and Echinodermata, whose hard parts have been thus, in a sense, preserved. Another fossil species—the Ostrea deltoidea—forms immense continuous beds in what is called the Kimmeridge clays of England and France. They extend for many miles about Weymouth; also in North Wiltshire, and in Yorkshire, in our own country, and about Havre, in France.

Comparison of the Living with the Fossil Creation.—Professor Phillips, some years ago, estimated the numbers of existing (or recent) animals and plants, and of the same in a fossil state, in order to show the proportions of the two. In that estimate the living creation was made to contain about 59,000 plants and 115,500 animals. The progress of discovery shows that we may with safety nearly double the numbers. But the proportions between living and fossil plants and animals are not materially affected, and we therefore append them in the following table:—

Proportion of the Living to the Fossil Creation.

Terrestrial Strata . . .	118 to 1.
,, Animals . . .	150 to 1.
Fresh-water Plants . . .	2 to 1.
,, Animals . . .	14 to 1.
Marine Plants	25 to 1.
,, Animals . . .	2 to 1.

But this table requires to be read with caution. As all these fossils are preserved in beds that once formed the bottoms of lakes or oceans, we cannot expect to find terrestrial plants and animals in them in such numbers as we find the shell-fish and zoophytes. The one class must have been carried thither by accident, such as inundations, &c.; the other naturally belong to it. While, therefore, we have of the first but a very imperfect representation, of the second we possess almost as great an abundance as we could desire. We may conclude this part of our subject by stating that organic fossils bear so general an affinity to existing life, that they may be *all* ranged in the same great *classes*, *most of them* in the same great *orders* and *families*, *some* in the same *genera*, and but very *few*—and these only in the latest strata—in the same *species*.

Division of Fossils.—By the various opportunities thus indicated we are enabled to divide all fossil relics into—

1. Petrifactions.
2. Bituminizations.
3. Metallizations.
4. Marks of vital action.

Petrifaction is the process by which stony matter, in a state of solution,

interpenetrates the pores of mineral and vegetable remains. If we bury bones in clay, mud, or lime, we shall find them in a year or two harder and heavier, and, in a word, rapidly assuming the appearance of true fossils. The process, indeed, is one that is constantly going on, under certain circumstances, even on the surface of the earth. The woodwork of a Roman aqueduct near Lippe, in Westphalia, is partly petrified. The wood and nuts of the hazel are found in a state of petrifaction at Ferrybridge, in Yorkshire, and on the shores of Lough Neagh, in Ireland. Springs containing lime, chemically dissolved, are familiar instances of petrifying power. Organic structures are not necessarily destroyed by petrifaction. Thin slices of fossil trees, when made highly transparent, will often show traces of vegetable fibre. Fossil zoophytes, of a calcareous origin, when steeped for some time in acids, will yield up the lime in a state of solution, and exhibit the original animal distinct in form, and sometimes in possession of its natural colour.

Bituminization.—When vegetables are left on the surface of the soil they rapidly decompose, and what remains to the eye is merely so much mould. But if subjected to moisture, and partly excluded from the sun and air, a semi-bituminous substance is formed, analogous to peat. And if they are completely buried, so that the volatile principles cannot escape, nor the air act upon them, and they are subjected to pressure, then bituminous matter will be formed in various states of purity, according as more or less earthy matter is mixed with it. What takes place in the earth during this conversion of vegetables may be judged by watching the effects produced on half-dried hay, which, when it is thrown into a heap, ferments, becomes black, and not unfrequently takes fire, and is consumed. Coal may be taken as one of the most common of these bituminous products.

Metallization.—Strata which contain fossils generally contain also metallic substances, such as iron. All metals can be dissolved as well as fused, and it is not difficult, therefore, to understand how they may be brought naturally into such a state as that they may enter the pores of vegetable and animal substances, in a manner corresponding with that already described in connection with petrifactions. All organic structures, after death, while in a state of decay, give off gases: water, of course, is present, entering, as it does, so largely into their substance; and thus the metals, the gases, and the water, acting chemically upon each other, produce compounds, which are slowly infiltrated into the pores, and thus metallic fossils are produced. Sometimes these fossils are so entirely metallized, that only the form and aspect of the plant or animal remain; sometimes the plant or animal is found essentially complete, but entirely penetrated throughout with the subtle metal; sometimes the fossil is merely covered with an incrustation of metallic salts; and sometimes, while the exterior alone is thus metallized, the interior remains stony or bituminous.

Marks of vital action, which refer obviously to animals alone, may be thus classed:—

Footprints of quadrupeds, of which the sandstones of Cheshire and Dumfriesshire afford good examples;

Holes made by certain animals in certain rocks—as, for instance, by the lithophagous conchifers in the Mendip limestone; and

Perforations made by one animal in the shells of another—as by the zoophagous mollusk in the valves of conchifers.

Results.—By all the various means thus indicated the geologist pursues his inquiries into the past history of the globe. Stratification shows him the various surfaces of that globe at different periods; and the very irregularities of the strata only increase our knowledge, by informing us of the strangely perplexed and troubled character of the events accompanying the gradual development of the material and half-chaotic crust into its present state of beauty and peace. Fossilization completes, as it were, the requisite information, by explaining how the world was peopled during the same periods, which are so widely divided in time, that no geologist who cares for his reputation will venture to assign to them any definite term.

We shall now present—in an arrangement chiefly founded upon, though somewhat modified, typographically speaking, from Professor Phillips's table—a complete view of the series of the strata as they are traceable in this country, and of their fossil contents, grouped into systems, and the systems again grouped into the chief leading divisions or formations known among geologists.

Superficial Accumulations.

Soils of various kinds, arising from the decomposition of vegetable and animal matter, and of the surfaces of rocks.

Alluvium, or deposits of clay, sand, and gravel, through the ordinary action of water.

Diluvium, or deposits of clay and gravel, formed by unusual operations of water, and accompanied with boulders, or great erratic masses of rock.

Tertiary Strata.

Clay, estimated at sixteen yards in thickness, consisting of a water-drifted mass of marine shells, pebbles, &c., resting on more regular shells, beds of sand, or sandy limestone. About forty per cent. of the shells are supposed to be identical with existing species.

Fresh-water Marl, about thirty-three yards thick, occurring only in the Isle of Wight, and including a bed of estuary shells.

London Clay, 100 to 200 yards thick, forming a mass rich in marine shells, of which three and a half per cent. are identical with recent kinds.

Plastic Clay, 100 to 400 yards thick, containing variously coloured sand and clays; the latter containing organic remains identical with, or allied to, those of the London clay.

It will be seen, therefore, that in this formation there is a small number of fossils identical with existing species.

Secondary Strata: Cretaceous or Chalk System.

Chalk, 200 yards thick, of unequal hardness, soft above, marly below, with interstratified flints; extinct zoophytes, *ananchytes*,* and other echinodermata.

Green Sand, about 160 yards thick, consisting of—

Upper Green Sand, very fossiliferous, in general chalky;

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* Fossils thus printed in Italics are especially characteristic of the strata.

Galt, a blue marl or clay, often very fossiliferous, and distinguished by the presence of the *Belemnites minimus;* and of the
Lower Green Sand, or iron sand, which is very fossiliferous in places.

Secondary Strata: Oolitic System.

Wealden, about 300 yards thick, and divisible into—
Weald Clay, with fresh-water shells, and containing *Cyprides;*
Hastings Sand, with land plants, and bones of *Iguanodon;* and the
Purbeck beds of clay and limestone, with fresh-water shells.
Portland Oolite, about 130 yards thick, formed of an Oolite limestone, locally variable, containing some beds full of fossils; and the Kimmeridge clay, with layers of ostrea deltoidea.
Oxford Oolite, about 150 yards thick, consisting of—
Upper calcareous grit;
Coralline oolite, with beds and masses of coral, *Echinida*, and many shells;
Lower calcareous grit, with *Ammonites catena*, and *Pinna lanceolata;*
Oxford Clay, Killarney Rock, } containing *Ammonites Calliovensis* and *Gryphæa dilatata.*
Bath Oolite, near Bath, about 130 yards thick, consisting of—
Cornbrash, a thin, impure, shelly limestone, with *Avicula echinata;*
Forest Marble, a shelly oolite, with concretionary sandy limestone;
Bath Oolite, in several divisions, in shelly, oolitic, compact, and sandy beds, containing Megalosaurus and Apiocrinus;
Fuller's Earth, a series of calcareous and argillaceous shelly beds;
Inferior Oolites, with Pholadomya and *Trigonia striata;* and
Sand, with concretionary masses holding shells.
Lias, about 350 yards thick, composed of—
Upper Lias Shale, full of characteristic Saurians, of Ammonites, Belemnites, and other shells;
Marlstone, replete with *Terebratula*, Pectinida, *Avicula inæquivalvis;*
Middle Lias Shale, containing *Gryphæa*, *Ammonites;*
Lias Limestone, with Gryphæa incurva, and Ammonites Conybeari; and the
Lower Lias Shale and coloured marls.

Secondary Strata: Saliferous or New Red Sandstone System.

New Red Sandstone, about 300 yards thick, comprising—
Coloured Marls, Gypsum, Rock Salt; Red and White Sandstones, and Marls; Conglomerate and Sandstone; } containing few or no organic remains.
Magnesian Limestone, about 100 yards thick, formed of the
Knottingley Limestone, with a few bivalves in the lower beds;
Gypseous Red Marls, having no fossils;
Magnesian Limestone, with shells and corals;
Marl Slate, containing *fishes* of remarkable forms; and the
Red Sandstone, in which plants of the subsequent coral series occur.

Secondary Strata: Carboniferous System.

Coal, about 1,000 yards thick. The subdivisions of the coal series are only

locally ascertained; gritstone and shale constitute the principal mass. Flagstone and ironstone are among the most characteristic layers. Fresh-water limestone and marine limestone are exceedingly rare and local. The shells are mostly of estuary origin. The plants are abundant, and mostly of terrestrial tribes and extinct genera.

Carboniferous or Mountain Limestone, about 800 yards thick, comprising—
Millstone Grit, a series of sandstone, shales, coals, and thin limestones, forming a transition group between the coal and the carboniferous limestones.

Yoredale Rocks, consisting of five or more beds of limestone, with alternating flagstones, and other gritstones, shales, thin coal, and ironstone.

Lower or Sand Limestone, in the north of England and Scotland, subdivided by sandstones, shales, and coal seams. They yield characteristic *Crinoidea*, *Productæ*, *Spiriferæ*, *Orthocerata*, *Bellerophon*, *Goniatites*.

Alternating Limestones and Red Sandstones, forming a transition group between the Carboniferous Limestone and Red Sandstone formations.

Conglomerates and Sandstones, in which no fossils have yet been noticed.

Coloured Marls and concretionary limestones, called corn-stones, with a few fossils; and lastly,

Tilestones, or Flagstone beds, with a few fishes.

All the fossils, through the whole of these Secondary Strata, belong to extinct species, and are different from those in the Tertiary Strata..

Primary Strata: Silurian, Upper Grauwacke, or Transition System.

Ludlow Rocks, about 660 yards thick, comprising—
Sandstones, with the fossil species of *Orbicula*, *Lingula*, Terebratula, Spirifera.
Limestone shale, with the Fossils *Pentamerus* and *Homonolutos*.

Wenlock Limestone, about 600 yards thick, formed of—
Limestone, } both containing corals and fossil Crinoidea in vast abundance, with Euomphali, Producta depressa, Orthocerate, Calymene
Shale, } Blumenbachii, and other Trilobites.

Caradoc Sandstone, about 830 yards thick, comprising—
Shelly Limestone and various Sandstones, with Pentamerus, Terebratula, Orthis, and Trilobites.

Landeilo Rocks, about 400 yards thick, consisting of calcareous flaggy beds, including Asaphus Buchii and other Trilobites.

*Primary Strata: Cambrian System.**

Plynlymmon Rocks, consisting of—
Argillaceous indurated slate, and sandy system slates, in which no fossils have yet been found; and—
Calcareous and argillaceous rocks, with Orbicula, Zoophytes, and other organic remains.

Bala Limestone, formed of calcareous and argillaceous rocks, with Orbicula, Zoophytes, and other organic remains.

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* This and the following (or Skiddaw) system are sometimes collectively spoken of as the Clay Slate system.

Snowdon Rocks, comprising variously coloured and indurated argillaceous slate. Few fossils have been observed in these rocks in Wales.

Clay Slate, a soft, dark slate, with no known fossils.

Primary Strata: Skiddaw System.

Chiastolite Slate, Hornblende Slate,	soft, dark slates, mixed with the minerals that give them respectively their names, and both apparently destitute of fossils.

Primary Strata: Mica Schist System.

Mica Schist beds, containing no organic remains, and composed of mica and quartz, alternate with gneiss, chlorite schist, talc schist, hornblende schist, clay slate, quartz rock, and primary limestone.

Primary Strata: Gneiss System.

Gneiss beds, composed of mica, quartz, and felspar, alternate locally with mica schist, quartz rock, and primary limestone.

In all the above primary strata the fossils belong invariably to extinct species, and often to extinct genera and families. They are different from the secondary and tertiary strata. The stratified argillaceous rocks comprised in the Cambrian and Skiddaw systems are not yet fully understood, on account of the rarity of fossils, and from other causes. The arrangements given, which are based on the labours of Sedgwick, are, however, correct with reference to the succession of deposits in the Welsh and Cambrian districts. The thicknesses are insufficiently known.

The unstratified rocks are now again reached, forming the general basement or floor of all stratified ones.

Succession of Organic Life.—In reviewing the strata and their contents, certain salient facts and deductions of high interest are impressed upon the attention. We perceive that as each of these strata contains the fossil remains of plants and animals that once lived on the land, or in the rivers, seas, and oceans, at or before the time of the formation of the strata, we are enabled, by combining together all the facts they collectively afford, to arrive at a tolerably accurate view of the succession of organic life on the globe—a most interesting theme, and which has tempted many scientific men into the construction of theories of greater or less ingenuity. The theory of progressive development, advocated in the well-known work on the *Vestiges of Creation*, is an instance in point. We shall not enter upon the consideration of such matters. We conclude our present chapter with a summary of the most striking facts that present themselves in connection with the known successional order of organic life.

Fishes are the only class of vertebrated animals which are found in all the systems of strata—a fact having an obvious connection with the aqueous origin of all the stratified rocks.

Reptiles begin to appear either in the carboniferous system or in the one above it, called the New Red Sandstone.

Birds and Mammalia appear but rarely in various localities in the oolite rocks; and it is believed that the amphibia, or fresh-water tribes of batra-

chida, are not discovered in either the primary or secondary strata. Lastly, as to

Man, the perfection, so far as we yet know, of all organized life—where does he first appear? The answer is, nowhere but in the loose surface soil, in mud, gravel, and caverns, and generally accompanied by pottery, bones, and other relics of the early industry of our kind. Can any more decisive evidence be afforded of the lateness of the period when man first trod the earth, of which he was to become supreme master, or of the incalculable ages—the unfathomable abysses of time, as we might rather call them—that must have elapsed before his home was deemed sufficiently prepared for him?

CHAPTER IV.

AGENCIES STILL AT WORK ON THE EARTH'S CRUST.

BEFORE we enter into the study of the respective strata, systems, and formations described in our last chapter, we will pause awhile to consider how far the crust of the earth is being changed or modified by existing influences. Obviously we must do this before we can consider ourselves in a right position for the study of its ancient history. Five grand divisions occur under which all these influences may be ranged:—

I. External, or Astronomical phenomena.
II. Subterranean, or Igneous.
III. Atmospheric.
IV. Aqueous.
V. Organic being.

The External Influences may be reduced to the effects of light and heat.

Heat.—All the variations of corpuscular and mechanical phenomena that are every where ceaselessly exhibited, both in organic and inorganic substances, may be ascribed to the unequal accession of heat from the sun unto our globe, which is constantly varying in distance, and whose parts are variously presented to the calorific rays, and to the unequal abstraction of heat by the cold ethereal spaces through which our planet revolves.

Light.—In light we recognize the chief element of change in the animal and vegetable creations.

Subterranean, or Igneous Influences.—Among the subterranean influences we may first mention one special effect of the distribution of the heat that rises from the interior of the earth—that is, the gradual change of level of certain parts of the land as compared with the general level of the ocean; as, for instance, on the shores of the Baltic, where certain parts are understood to be slowly rising above the sea. Whether this elevation is counterbalanced by corresponding depression elsewhere is not at present known. Sir Charles Lyell thinks the sum of the depressions from this cause greater than the elevations, but no proof is given. On this important but obscure point we shall quote the words of the author of the article "Geology" in the *Penny Cyclopædia*, who says, "If there be in the earth a pervading high temperature, which diminishes from the interior toward the surface, it appears, from

Sir John Herschel's reasoning (given in Babbage's *Ninth Bridgewater Treatise*), that along the shores of the sea, the isothermal * lines of the interior of the globe should rise, because of the continual deposition of imperfectly conducting sediments there. For then the radiation of heat along these lines would be diminished until the interior heat had come nearer to the surface. By the consequent expansion of the subjacent earthy substances the sea-shore should rise, and thus the addition of sediment from watery action, and the effect of the effort to restore equilibrium in the disposition of the interior temperature, would, upon the whole, coincide in minutely raising the surface of the sea." This comparatively regular action of subterranean heat must be carefully distinguished from the highly irregular one, to which we owe earthquakes and volcanoes.

Earthquakes form the most terrible of all natural phenomena. They make the solid globe itself tremble and quiver beneath our feet, and sometimes to appear to the eye to undulate like the waves of the sea when agitated by the wind. They break up the crust of the earth, elevating it here into hills, depressing it there into valleys; seaming it with rents and fissures, from which often arise products never before known in the district; altering the course of rivers; producing new shores and beaches; raising the sea-bottom up to become dry land, and depressing the richly-wooded land to become henceforth the bottom of the sea; leaving cities that overhung the ocean several miles inland, and submerging other cities again below the waters; altering the distribution of animal life, and occasionally destroying it to a vast extent. Let us mention a case or two by way of illustration. In 1822, a tract of territory on the Chili coast, above one hundred miles in extent, was raised from two to six feet; and the sea-bottom, thus laid bare, emitted for a long time the most intolerable odour from the decay of dead fish, &c. In 1596, on the other hand, several Japanese towns were covered by the sea.

Volcanoes and earthquakes are doubtless but manifestations of the same subterranean fires, operating with different degrees of force, and perhaps, also, under somewhat different circumstances as regards the superincumbent masses. Thus when, in 1759, the new volcano of Jornollo was formed on the plains west of Mexico, it was what we should call an earthquake that caused the ground to swell upward like a bladder to the extent of two or three miles, and which then, bursting, became a volcano, and ejected such masses of materials that a mountain 1,695 feet high was formed by them. But the effects of volcanoes in modifying the earth's crust are even yet more extensive than such events would suggest. The burning lava emitted by them has been known to issue (as from a volcano in Iceland) in such profusion as to form a slow-moving river of melted rock, fifteen miles broad, from 100 to 600 feet deep, and extending, before it finally rested, to fifty miles from the place of its issue. It is chiefly near the sea-coast that the volcanic phenomena of modern times are found—a fact which seems to show that the admission of water to the buried fires beneath is necessary to rouse them into such a state of terrible activity.

Effects of Volcanic Action on the Bed of the Sea.—The bed of the sea is supposed to be materially affected by volcanic forces. Thus islands are

* Curves traced on a map or globe, so that each shall pass through a series of localities, where the mean annual temperature is the same.

raised, as in the South Seas, which then become centres of aggregation for all sorts of matter floating in the waters or in the air, are soon covered with vegetation, and lastly, with organic life, both of which alternately decay and spring up in never-ending sequence, and all the while increase the magnitude of the parent soil, while encroaching upon, and thereby decreasing, the size and depths of the waters around. But this kind of action may be going on invisibly to us in innumerable parts of the seas and oceans, without being sufficiently powerful to raise the lifted rocks above the surface. Of course here again corresponding depressions take place; but whether to an equal amount is not known. Even in that case we perceive that the general result of volcanic action beneath the seas and oceans must be a partial deepening and contracting: therefore still change—ceaseless change. The constancy of the earth's dimensions, as indicated by the unvarying length of the solar day, may be supposed sufficient to determine the fact of an equality in these results; but that is by no means the case, for such changes, however important in the main, if we think of them as operating through a million or two of years, become apparently insignificant when thought of only in connection with our historical period.

Atmospheric Agencies include the air itself, rain, frosts, winds, and electrical phenomena; and their combined effect is to wear down, mechanically and chemically, the surface of all rocks, and to create soil, part of which is gradually strewed over the land, and becomes the means of vegetation and organic life, while the remainder is carried away by rivers and running waters towards the oceans, seas, or lakes, into which they flow.

Air acts potently upon all substances, even the hardest, that are exposed to it, through the chemical action of its oxygen and carbonic acid. Oxygen eats away the metals—carbonic acid bites into the substance of rocks—and both together at last reduce the surfaces upon which they act to a mere powder. As one layer, as it were, is worn away, another is ready to be attacked; and so the process goes on without cessation. Thus iron is reduced to rust; thus granite is pulverized to soil—an operation which, it is said, has been effected to the depth of three inches within twice as many years.

Rain enters the fissures of rocks, softening and dissolving them, both by its chemical and its mechanical powers, and so preparing the way for the still more destructive agents that follow, as frosts, &c. It forms floods and inundations when it continues for a long time, which may sweep whole villages before it. On the other hand, it exerts a most beneficial effect in promoting the growth of vegetation. Its very floods, indeed, in certain parts of the world, produce the same effect on a large scale as in the annual flooding of the Nile, for which the people of Egypt look always with such welcoming anticipations. The fall of rain varies greatly in amount in different parts and different seasons. Thus, in Bombay, the monthly depth of rain in June has been given as twenty-four inches, and in October as only between one and two inches. In London the depth varies from between eight and nine inches in the half-year from January to July, to between twelve and thirteen inches in the remaining half-year. Whatever the influence exercised by rain at present, that influence was, in all probability, much greater in remote geological periods, when the heat was so much higher, and when, therefore, more liquid matter was drawn up in vapours into the sky, to descend again in rains.

Frost.—Wherever rain can insinuate itself, as already described, into the crevices of rocks, there is left an opportunity for the evolution of a highly destructive principle—the expansion of the liquid particles by freezing, and the consequent rending asunder of the rocky surfaces, which, thus enlarged, can receive still larger quantities of rain, to be again frozen and expanded, and so on endlessly. This is one of the various modes of operation in which frost exhibits its power of modifying the earth's crust. Avalanches and icebergs show it in its grander manifestations of the same force.

Avalanches originate in the higher regions of mountains, and are formed of gradually accumulating masses of snow, which at last become so ponderous, that the inclined planes on which they rest can no longer support them, and they are hurled down into the valley beneath, often destroying villages with all their inhabitants, filling up rivers so as to change their course suddenly, and scattering abroad the rocky débris which they have brought down with them.

Icebergs are immense bodies of ice, extending occasionally two miles long by one broad, and some hundreds of feet high, which are found floating in the polar seas, and are formed in two ways—in the sea itself, by the accumulation of snow and ice, or on precipitous shores, in glaciers, which are ultimately broken off by their own weight, and often carry with them enormous pieces of rock. These, as the icebergs melt, when floated into warmer regions, are dropped, with all their lesser earthy contents of gravel, &c., to the bottom of the ocean, and so help to raise its bed. The erratic masses of stone called boulders, found scattered in various parts of the world on the surface, without any apparent connection with the rocks in the crust beneath, are supposed to have been thus deposited in some remote time, when the locality was covered with the deep waters.

Winds raise waves—which again act upon the rocky shores—uproot forests, cover green valleys with barren sand-drift, and form extensive *Downs*, as we call those tracts of land which extend, generally at a high level, by the sea-shores.

The Electrical Phenomena, which exert a sensible action on the surface of the earth's crust, are as yet but imperfectly studied. We are impressed by thunder-storms, for we can at once appreciate the strength of the power which sets fire to extensive forests, and shivers houses and rocks, and which not unfrequently reduces the human form in an instant to a mere blackened cinder; but it is probable that the slow, imperceptible effects of electricity are of infinitely greater importance in the production of specific geological effects. How intimately connected with all chemical and vital action that power is which we know under the various names of electricity, galvanism, and magnetism, is a recognized truth; but we are unable, as yet, to measure its precise effects or mode of operation. One single fact may illustrate sufficiently for present purposes the influence this power must exert in continually modifying and changing the earth's crust:—The hardest, and, to all other powers, most intractable of substances, can be artificially dissolved and re-organized by the chemist with its aid.

Aqueous Influences.—What the atmospheric agencies thus break down, the aqueous, to a great extent, carry away; and in so doing still further help on the grand operations of modification and change of the earth's surface.

Springs open out channels, which may ultimately become river-courses.

They dissolve the rocks and minerals between, over, or around which they pass. Sometimes they exercise a petrifying power; and if heated to a high temperature, their ordinary chemical and mechanical forces are greatly increased. Unless very pure, they also carry down to the rivers into which they discharge themselves the débris collected in their course.

Rivers perform this latter operation on a great scale, often carrying down towards their mouths such quantities of mud, sand, gravel, &c., as to form vast plains, called deltas, like those of the Ganges and the Nile. But rivers are destroyers as well as carriers. We refer to the process known in geology as—

Denudation—a word meaning to lay bare, and devoted to the expression of the effects of running water in the removal of solid matters on the surface, and thus of laying bare some rock beneath, which is then said to be denuded. The power of rivers in this way has been reduced to the following calculation:—If the speed be three inches per second, fine clay will be torn up; if six inches per second, fine gravel will be raised; if twenty-four inches, rounded pebbles an inch in diameter will yield to the momentum; whilst a speed of thirty-six inches in the second is sufficient to drive along angular stones as large as a hen's egg. The effect of such forces, when operating through a long period, is almost incredible. There are gorges in the valley of the Alps 600 to 700 feet deep, which have been thus scooped out. The great cataract of Niagara has receded, under the operation of this power, fifty yards in less than as many years of the present century. These facts show the ordinary action of rivers; but when swollen so as to overflow their banks, a new class of effects are produced on the surrounding land, and which are often of a very serious character.

Effects of River Sediments on the Sea-bottoms.—The sediments thus formed by all the foregoing influences, and borne along by springs and rivers, are deposited by the sea-shores, and are therefore steadily diminishing the depths of the sea. Now, as the quantity of water on the globe is supposed to be constant, this change in the sea must be accompanied by an increase of the whole watery or oceanic area, or the surface must rise. The former is probably the truth. As much land is probably worn down in one part by the action of the waves as is wasted in another by the deposition of sediments. For such waves, by their restless agitation, undermine the cliffs that are above their level, grind away the rocks that are covered and uncovered during every ebb and flow of the tide, and form out of the materials at its disposal, here a dangerous sandbank—there a cultivatable piece of land, out of what was merely the sea-shore.

Organic Influences are, perhaps, the least important of all those we have named in their effects upon the crust of the globe. They are not, however, to be passed over in silence. Their effects may be summed up generally thus:—They increase the superficial soil—or that which, at some time or other, has been the superficial soil—by their decay after death, and the fresh luxuriance of organic life to which the decay gives rise by the increase of its food; such organic life again decaying, and so on perpetually.

Plants living in the sea do not probably materially affect the crust, except by their support of animal life, which, as we shall presently observe, has a noticeable effect on the sea-bottom. But terrestrial plants play a more conspicuous part: witness the formation of great bogs, which we often find (as in Ireland) to cover a very extensive space, and to sink to a considerable

depth—the coal measures a thousand yards deep—and the accumulation of trees and other vegetable matters, which are carried down towards the sea in such vast quantities through the greater rivers of the world; as, for instance, in the Mississippi, where what are called rafts, formed of tangled trees, roots, and brushwood, are found several feet thick, and several miles in length. The snags, that is, trunks of great trees, buried in the bed of the same rivers, and which frequently project so high as to endanger steam-boats, also suggest how great an influence vegetable remains may exercise, under certain circumstances, in changing or modifying the superficial configuration of particular localities.

Plants have at the same time, be it observed, a great conservative tendency. Their matted roots bind together the loose sand of sea-shores, and generally everywhere protect the soil from the power which wind and heavy rains, or inundations, would otherwise exercise over it.

Animals.—We have already had occasion incidentally to notice the wonderful agency of animal life in building up large portions of the actual surface of the earth. We may still further illustrate this point by a few words upon that most interesting of animalculæ, the coral, whose structures have been a never-ceasing theme of admiration with the poet and naturalist. The animal itself is scarcely so big as a pin's head, is of a soft gelatinous structure, and star-shaped; and in order to form a single branch of coral, millions of them must unite their tiny bodies together. Yet this small, almost invisible creature, through its power of secreting lime from the water, will raise solid structures in the sea capable of resisting the wildest attack of the waves, and which shall extend to immense distances. There are groups of coral reefs in the Pacific extending from 1,100 to 1,200 miles in length, and from 350 to 400 in breadth. Sometimes the reefs appear as islets; sometimes as circular belts, inclosing a sort of lagune, or lake, within; but generally in long ridges, averaging in width from 20 to 100 feet thick. The circumstances under which these tiny architects labour make the results the more wonderful. "No periods of repose are granted," says Mr. Darwin, an intelligent observer, "and the long swell caused by the steady action of the trade-wind never ceases. The breakers exceed in violence those of our temperate regions; and it is impossible to behold them without feeling a conviction that rocks of granite or quartz would ultimately yield and be demolished by such irresistible forces. Yet these low, insignificant coral islets stand, and are victorious; for here another power, an antagonist to the former, takes part in the contest. The organic forces separate the atoms of carbonate of lime one by one from the foaming breakers, and unite them into a symmetrical structure; myriads of architects are at work day and night, month after month, and we see their soft and gelatinous bodies, through the agency of the vital laws, conquering the great mechanical power of the waves of the ocean, which neither the art of man nor the inanimate works of nature could successfully resist." The coral rocks are not, of course, raised directly from the ocean's bottom, but on the summits of hills, and probably of volcanic peaks, both of which are, perhaps, far more numerous at the bottom of the ocean than on the land. Thomas Montgomery, the author of the *Pelican Island*, gives us the following fine passage descriptive of the labours of the coral animalculæ:—

"Millions of millions thus, from age to age,
With simplest skill and toil unweariable,

No moment and no movement unimproved,
Laid line on line, on terrace terrace spread,
To swell the heightening, brightening, gradual mound,
By marvellous structure climbing towards the day.
Each wrought alone, yet all together wrought:
Unconscious, not unworthy instruments
By which a hand invisible was rearing
A new creation in the secret deep.
Omnipotence wrought in them, with them, by them;
Thence what Omnipotence alone could do,
Worms did. I saw the living pile ascend,
The mausoleum of its architects—
Still dying upwards as their labours closed:
Slime the material, but the slime was turn'd
To adamant by their petrific touch.
Frail were their frames, ephemeral their lives,
Their masonry imperishable."

On examining a piece of coral, its surface is perceived full of little openings, each of which contains one animal: the whole coral pile, therefore, is as a vast house for the family, in which house each individual has its own apartment. Shell-fish, on the contrary, which possess the same power of secreting lime, use it to form a separate shell for each individual, and which has no connection with that of any other individual, except that of mere contiguity. Oysters, muscles, and cockles are thus separate, even while forming together beds of many miles in extent. After what we have seen of the power of the coral animalculæ to affect the earth's surface in the ocean depths, we need not be surprised at the statement that these, and the other tenants of the waters belonging to such tribes as the zoophyta, testacea, &c., flourish in such amazing profusion, that their very exuviæ tend markedly to fill up the almost boundless depths where they inhabit.

Care necessary in judging of the ancient from the modern effects of the foregoing influences.—Although we everywhere recognize through all nature fixed laws, we also as universally behold varying conditions under which they act. It is not, therefore, to be assumed that what changes we now see going on in modern times are in themselves a sufficient measure of comparison to estimate the force of the laws causing these changes in remoter ones. Light and heat, for instance, are phenomena exhibiting certain regularities of action called laws: we see the results of their action now; we know the source of light and heat was the same in all past time; and we may, therefore, naturally conclude that their effects were very much the same then as they now are. But, as it has been well pointed out, let the sun's rays be but supposed to fall upon the earth in smaller quantity, through the augmentation of the minor axis of the earth's elliptic orbit; let the temperature of the ethereal spaces rise; who does not see that all the effects depending on the external excitant forces would immediately change? Now this very orbit *is* variable.

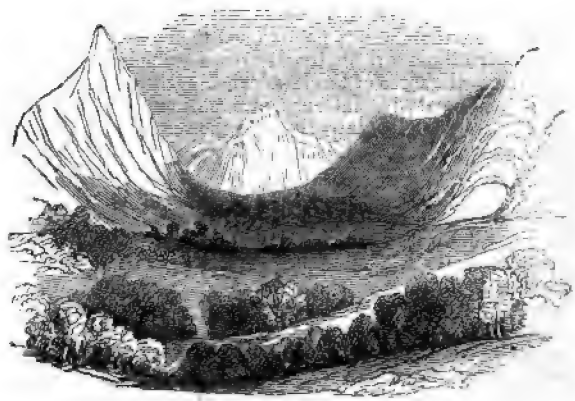
Also to allow for possible causes, of great moment in their results, but of which no traces remain.—Again, what physical changes may not be wrought by a cause of so trivial a character that, while its effects might modify the entire future of the globe, it should leave not a trace of itself behind! Suppose, for instance, an earthquake were to sink the Isthmus of Darien but a hundred or two feet below its present level, who can estimate the effects upon the Indian, Mediterranean, Atlantic, and Pacific oceans over areas of

enormous extent, and affecting the stratified deposits and physical conditions, and consequent variations, in the relative abundance and geographical distribution of organic life? These and similar facts show how humbly the geologist should pursue his researches—yet how earnestly and unremittingly—if he would base his noble and beautiful science on solid foundations.

Nature's efforts for an Equilibrium.—And, independently of the various truths involved in the phenomena we have glanced at in the preceding pages, what—it may be asked—is the higher meaning of the whole?—the objects sought by all this incessant change and conflict? We may answer, in the eloquent words of the Cyclopædist writer already referred to, "The never-ceasing activity of the powers of nature is an inextinguishable, though an unavailing effort to restore an equilibrium which is incessantly disturbed. The Protean changes of the atmosphere; the varying effects which its chemical and mechanical energies occasion among the masses of dead matter and the forms of life; the flowing of the ocean; the subterranean fire, and wide wasting of the earthquake, are all efforts to obtain rest, consequent on a succession of perturbations. In this sense, not the earth only, but all the solar system—and, perhaps, all the extent of the heavenly spaces—conceivable rather than visible by man—is in the condition of instability described in the Pythagorean philosophy, *Nihil est toto quod perstet in orbe.*"

CHAPTER V.

GRANITE AND THE PRIMARY ROCKS.



MOUNTAINS OF GRANITE AND MICA SLATE, GLEN SANNOX, ISLE OF ARRAN.

On the Successional Order in which Strata should be described.—We commence our description of the different rocks, unstratified and stratified,

at what we may call the base of the geological structure. In proceeding from the surface, or latest formation, down to the granite, we take the course that naturally offers itself to us, as residents on the surface. We have been familiar with this first, and have only delved down from it as our material wants and our scientific aspirations suggested. We have, therefore, presented all the geological formations in this order in the table that we gave in our third chapter. On the other hand, when we come to describe these formations, it is obviously unnatural to begin at what was but the last of a series of operations, all connected with each other in the due order of cause and effect. We will, therefore, commence with the unstratified or igneous rocks.

Plutonic and Volcanic Rocks.—These are divisible into two great classes: 1, the Granitic, or, as some geologists call them, the Plutonic; and 2, the Volcanic. We shall speak of the latter in a subsequent portion of these papers.

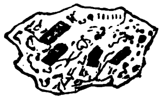
Igneous Rocks not always preceding the Aqueous.—It is important that the student of geology should bear in mind that although, as a broad general rule, the igneous preceded the aqueous rocks, it by no means follows that all the igneous rocks are older than all the aqueous ones. The reverse is very often the case. It is highly probable that the same state of things which originally produced granite during the very earliest period of the earth's history continued still to exist, and to be in operation at limited depths in the earth's crust, long after sedimentary rocks had been deposited. Volcanic formations are still constantly rising under our very eyes, and we need not, therefore, speak of *their* comparatively modern date in many instances.

Granite sometimes formed later than the Rocks that lie above it.—As at once a proof and consequence of the production of granite later than some of the rocks that overlie it, we may instance the many known examples of the upward flow of fluid granite into fissures of the latter, just as in our iron furnaces the melted ore is found to penetrate, as veins, into the centre of the sandstone walls. Sir Charles Lyell, indeed, thinks that granite may be still in process of formation, through the melting of the rocks that lie above it when exposed to the earth's intense interior heat, which thus lessens their amount, destroys what organic remains may have existed in them, and reduces the whole into a part of the general mass of the interior of the earth. Such speculations show us, among other legitimate deductions, that incalculable as geological eras of time already are made to appear, by what we see in the crust, even that crust itself can give us but a part—possibly a small one—of the whole truth. So that the history of an individual world seems scarcely less wonderful than that of all the bodies of space, where, when one has arrived at last at something like the comprehension of a universe, he finds that, instead of being at the end of his journey, he is scarcely nearer to it than when he set out, for now he discovers a plurality of universes, if we continue to use the term universe in the same sense in which we have previously understood it.

Granite, general description of.—Granite presents itself in many forms—now as stupendous mountain ranges, such as the Alps, the Pyrenees, the Grampians; now as a floor of an undulating form; now as veins bursting up through the strata above, and ramifying in a thousand different shapes; everywhere presenting in its forms proof of its originally igneous state. In what is called granite districts—that is, where granite appears above the

surface—the scenery is of a rugged as well as mountainous character, to which the snow-clad peaks often lend a strangely harmonious combination of the soft and the beautiful with the grand and the desolate.

Structure of Granite.—In itself granite is one of the most beautiful of rocks, both as regards structure, variety of constituents, and colours. It is composed chiefly of mica, felspar, and quartz, in distinct crystals; but it is also found to contain hornblende, garnet, talc, and numerous other minerals. The crystals of the mica and felspar are often of great beauty, while the quartz commonly fills up the interstices between the two. The colours are extremely various. Felspar is found red, grey, yellow, white, green; mica—black, grey, white, brown, or silvery; quartz is generally clear white or grey; hornblende dark green or black. The individual grains of the component parts of granite can be clearly distinguished; sometimes they are small, as in the Aberdeen granite. Mica is found in laminæ, some inches across; also in small plates. The felspar in graphic granite forms almost one huge crystallized mass. This latter derives its name from the circumstance that the minerals in it are occasionally found arranged in a manner that has been likened to the lines of Arabic writing.



GRANITE.

The Uses of Granite are chiefly confined to building, and some of the most extraordinary structures of the world have been formed of it; for instance, the Egyptian pyramids. Its extreme hardness renders it of pre-eminent value for all edifices of a permanent character. The granite used in London for Waterloo Bridge, and for the river wall of the New Houses of Parliament, was brought from Aberdeen, where it forms the ordinary building stone. Of late years the red granite of Peterhead, in Scotland, has been used for vases, chimney-pieces, &c.: it is brought by machinery to a high polish. Mica and talc may be occasionally found in single crystals of a foot or so square, and then become admirably fitted for splitting up into thin transparent plates, that may be used instead of glass. Some believe the Romans used such plates for the garden frames in which they grew early fruits and flowers. Talc will bear a higher heat than glass without injury; and, when used in ships of war, is rendered less liable to break by the explosion of ordnance. The Chinese use decomposed felspar in the manufacture of their best earthenware; and we ourselves have found it of such value for the same purpose, that many thousand tons are annually brought from Cornwall to the English potteries.

Primary Rocks: Gneiss and Mica Schist Systems.

Formation of Gneiss and Mica Sehist.—As the crust of the earth cooled under the operation of the influences described in Chapter I., it appears to have crystallized into granite. That was the first step in the economy of creation. The next was produced by the combined influences of this gradually lessening heat, and of atmospheric and watery action upon the surface. Hence the strata known under the names of the Gneiss and Mica Schist systems. These are, unquestionably, the oldest watery deposits known, and have probably preceded the period of the existence of life in any shape. They also extend so largely over the world as to approach nearer to universal formations than any of later date. Nowhere do we find any trace of their formation in the present time; they seem to be altogether

productions of the past. The peculiar circumstances under which they were formed appear to be these:—The internal heat of the earth had cooled down sufficiently to allow of a certain action of water, without the latter passing off into steam, but was yet too hot, and in other respects unsuitable, for the appearance of organized beings.

Popular Rock Classification.—Let us here pause for a moment to remark that all the stratified rocks of geology may be presented under one very simple and instructive aspect—that of their essential constituents. Thus—

The Silicious, or Flinty series: commencing with granite, and passing through the gneiss and mica schist rocks, the grauwacke, sandstone, and sand.

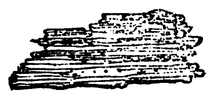
The Argillaceous, or Clayey series: including gneiss and mica schist, clay slate, slaty shale, laminated clay, and alluvial or common clay.

The Calcareous and Granite, gneiss and mica schist, crystalline marble, limestone chalk, and common marl.

The Carboniferous: commencing with coal, the product of the decay of organic (vegetable) life, and following from this, in order of intensity of effect, not, as in the previous instances, resulting from it, lignite and common peat.

Structure, &c., of the Gneiss and Mica Systems.—As might naturally be expected from a consideration of the facts already mentioned, gneiss and mica schist consist essentially of the same substances as granite, but altered in their relative proportions, and having various other minerals added. But the most important distinction between the two classes of rocks is in the structure. Granite, as we have pointed out, is crystallized; each mineral in it forms an individual independent crystal, or at least occupies the space left vacant between crystals. In gneiss and mica schist, on the contrary, the very same materials —the felspar, quartz, and gneiss—are rolled, or rounded, or in fragments, evidently the result of watery action. Again, granite presents no appearances of lamination or stratification; whilst gneiss, however hardened or contorted by the rough treatment it has undergone, in the then chaotic condition of the globe, always reveals both these characteristics in its structure. There can be no difficulty, therefore, in saying the fragments worn down must have been deposited in a sediment, and heat and pressure did the rest. These structural differences are illustrated in our engravings.

GNEISS.



MICA SCHIST.

Illustration of the Heat existing during the formation of Gneiss and Mica Schist.—It is interesting to observe how often in geology some accident reveals important portions of history. The garnet does this for the systems under review; for the fact that it is found in them shows that the rocks in which it is imbedded must have assumed their present condition under a heat powerful enough to form that mineral by fusion, but which could not melt the constituents of the rocks themselves, or they would again have become crystallized, as in the original granite.

Scenery of Granite, Gneiss, and Mica Schist districts.—The engraving at the head of this chapter is a glimpse of the kind of scenery that exists where there is a predominance of granite, and gneiss, and mica schist rocks on the surface. The granite generally in such cases, forms the projecting

mountain peaks, and the hard angular precipices; while the gneiss and mica schist occupy the lowlier sites, and the rounder outlined masses; for the latter being softer, lose their angularities sooner than granite. The gneiss or mica schist rocks occur abundantly in our own country, especially in the Scottish highlands and isles. Some of the most picturesque effects of highland scenery, with its deep glens and precipitous mountain and hill sides, are found among them.

Uses of Gneiss, &c.—The uses of the rocks of these systems are not remarkable. The primitive limestones which they include make valuable marbles. Vases are formed from stea schist, the *lapis ollaris* of antiquity. Flexible asbestos is found among the mica schists, and is used for the construction of fireproof fabrics. Of their mineral contents the garnet is the chief: the finest examples of this stone are dug up from among these rocks. Tin and copper also occur in veins running through them.

Clay Slate (Cambrian and Skiddaw), Grauwacke, and Silurian Systems.

Clay the distinguishing Constituent of these Rocks.—At length we touch upon the boundaries of life, and, where that begins, the primeval chaos must be nearly at an end. Before we ask ourselves what life it was that thus early ventured forth from the womb of time, let us notice the material changes that prepared the way for it. As flint, or silica, was the characteristic of the gneiss and mica schist systems, so is clay the distinguishing feature of the systems named above. We may also observe that the clayey or argillaceous rocks of this series bear the same relation to the flinty gneiss and mica schist as the clays and the sands upon which we now walk. Fineness of particle seems to be the only essential difference distinguishable between the mineral constitution of many sands to clays. We can, therefore, readily understand how particles worn down from the same rocks (of mica schist, for instance), may have been separated, and carried by the waters to different distances, and ultimately deposited in altogether distinct beds. And thus, also, is explained the fact that the gneiss and mica schist rocks are seldom found to any extent in the same districts as the clay slates, and that, in consequence, the latter not unfrequently rest on the granite rocks, without any interposition of gneiss and mica schist, as in Cornwall and Cumberland.

Clay Slate.—The distinguishing peculiarities of the clay slate, grauwacke, and Silurian systems may be thus described:—Clay slate consists almost entirely of argillaceous compounds. It is found in beds of immense thickness, with a fine grain—sometimes hard and splintery, sometimes soft and easily worn away—glistening aspect, and of various colours—green, black, bluish, mottled, and purple. There is a group of slates and flagstones near Snowdon, in North Wales, fifteen thousand feet thick.

Grauwacke.—Here the argillaceous compounds are mingled with arenaceous, or sandy strata, the whole forming an aggregate of clay, quartz grains, or sand, felspar, and mica, with fragments of jasper and other minerals. The structure is variable. Grauwacke may be found as fine as a coarse slate, and as rough as a mere conglomeration of pebbles.

Silurian.—The limestones which occur partially in the previous systems now appear much more frequently, so that the argillaceous compounds are here largely blended with calcareous matter. The rocks of the grauwacke

and the Silurian systems are not readily distinguishable, except in their native masses. These show that the latter formation contains more frequent alternations of strata, have suffered less alteration from heat, and are generally of a looser texture, suggestive of their higher state of preparation for the beings they were to nourish.

Superficial Characteristics of these Rocks.—As a whole, we may say of these argillaceous stratas generally, that they are widely distributed, and possess strongly-marked superficial characteristics. The blue, grey, green, or purple colours, the generally fine grain, the laminated structure—often exhibiting, also, regular symmetrical joints—and, lastly, what is called the quality of cleavage in the clay slate, which enables us to split it up into thin plates at nearly right angles to the line of stratification, are all features that at once arrest the eye of those who see them for the first time, and cause them to be easily remembered and distinguished afterwards.

Slate Cleavage.—This curious phenomenon, the cleavage, is attributed to heat, which, while sufficient to produce that entirely new form of material structure, was still moderate enough to allow of the development of the new and infinitely greater wonder, organic being; or, supposing it to have taken place at a later time, and under circumstances that caused life in that special locality to be destroyed, the heat was still insufficient to destroy the organic remains which were to tell us their history. To that theme we now address ourselves.

First appearance of Life on the Globe.—As all we know of the animal and vegetable life of the world in remote periods is derived from the petrified remains of certain plants and animals, it is important to consider how far this fossil record is complete. Obviously it is incomplete. On the one hand, we cannot, for an instant, suppose that specimens of every living thing were deposited in the sediments that ultimately became rocks, and then reduced their organic contents into the same hardened materials as themselves; nor, on the other, can it be supposed that we have exhumed anything like a complete set of the specimens that have been thus preserved. But even rocks have been subjected to such heat as would destroy their inclosed fossils. Above all, there are the seas and oceans, of whose bottoms we can know nothing, covering the larger portion of the entire crust of the earth. All these sources of imperfection must be kept in view in examining the geological records of life.

Lowest strata in which Organic Remains have been discovered.—It was long supposed, nor is the idea yet abandoned, that the Silurian was the lowest system in which organic remains had been discovered. The name Silurian, let us observe by the way, was adopted to indicate the fact, that the beds which compose that system are largely developed in that part of the West of England which was occupied in the Roman period of domination by the Silures. But organic remains have been discovered of late years below the Silurian base in England, and in strata in America, which the geologists of the country believe to be also of earlier formation. It is possible, therefore, that life commenced with the gneiss and mica schist systems; and the beds of limestone comprised in it are especially noted in connection with this hypothesis.

The earliest Living Things.—And in what form does this great revelation first present itself? The answer is—the very humblest; in markings produced by fucoids (a tribe of sea plants), in the lower Silurian rocks of

Russia. Thus the food of animals preceded, as we might naturally suppose, the animals themselves. Of the latter, the earliest appear to have been the polyparia, already described, the builders of the gigantic coral reefs; the Graptolites,a family allied to the sea-pens of modern oceans, which burrow in the sand and slime of deep water; and the Crinoidea, a kind of star-fish, fixed on the top of a flexible stalk, rising from the sea-bottom, one of the very lowest of animals in its organization, possessing arms to catch its food, and a stomach of one aperture to digest it, and nothing more—eaters for eating's sake, one might be apt to say; but the meaning of its peculiar structure seems to be partially, at least, indicated, when we learn that it belongs to the echinodermata, the police of the seas, which do not simply arrest the troublesome mobs of those lower regions, but devour them, and so keep the way clear. There have been also found in the Silurian formations examples of the annelida, or sea-worms; of the crustacea, represented by one almost omnipresent animal, the trilobite, an inhabitant of the sea, not unlike our wood-louse; of the mollusks, including, among many less highly organized species, the nautilus and cuttle-fish. All these belong to the inferior of the two great divisions of animal creation—the vertebrated and invertebrated, the first having a back-bone, and the higher nervous system which that structure implies; and the second wanting that structure, and therefore possessing only a lesser degree of nervous development. But a few faint, yet highly important traces have been discovered in the Silurian system of fishes, the first step in the ascending scale of vertebrated animals.

The results, therefore, of all these facts may be summed up thus:—

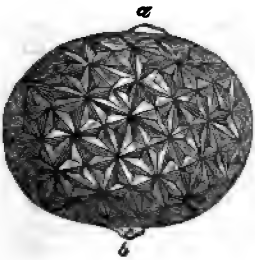
Dry land existed during these systems, and gave birth to plants, chiefly, if not entirely, in the upper strata. There are no traces of land animals.

The marine animals were probably very few in the older, and grew more numerous in the later parts of the systems.

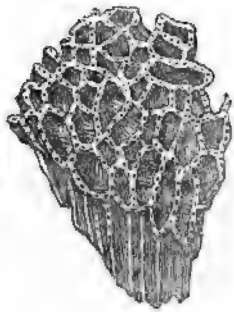
There is no particular degree of simplicity in the structure of these, the earliest animals; nor within certain limits are they confined to the lowest classes of organized beings. At the same time, the lowest vertebrated animals do but just appear in them; and the higher—reptiles, birds, mammalia—are unknown.

CHAPTER VI.

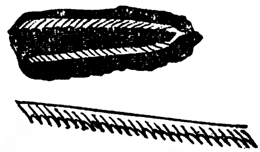
PRIMARY STRATA—CLAY SLATE, GRAUWACKE, AND SILURIAN SYSTEMS—*continued.*



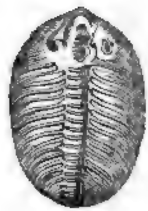
1. *Spænorites Balticus.*



2. *Catenipora escharoides.*



3. *Graptolithus Murchisonii.*



4. *Ogygia* (*or Asaphus*) *Buchii.*

Earliest Living Things (*continued*).—Few persons, we imagine, can look at the extraordinary creatures shown in the above design without something like a thrill of emotion, when they are informed these are among the *very earliest* (*known*) *forms of animal life.* One of the very oldest of all appears to be that we have placed first—the *Spænorites Balticus*, which belongs to the family of Radiata. The mouth is at the upper side, *a*, and a stem, rarely found with the fossil, extended from the opposite extremity, *b*. It is found in the Llandeilo rocks, in Wales. The beautiful chain coral (*Catenipora escharoides*) illustrates the general richness of the Silurian formation in the family to which it belongs. It is widely spread through Europe. The *Graptolites* are here represented by the *G. Murchisonii*, as found in the shales of the Silurian system. They are believed to be related to the genera Pennatula and *Virgularia*, and if so, were doubtless, like the existing species belonging to these genera, accustomed to live in mud and slime. Lastly, the trilobites appear before us in the person of the animal named *Ogygia* (or *Asaphus*) *Buchii*. This family of crustaceans was to the Silurian seas what our crabs and shrimps, &c., are to the seas of modern times. Upwards of two hundred and fifty species of trilobites have been already drawn and described. They are supposed to have swum at the surface of the water, in the open sea, and near the coasts, feeding on their smaller marine companions; and to have been able, when themselves threatened with any unpleasant consequences, whether by way of retaliation or as merely an incident in the same

> "Good old plan,
> That he should take who has the power,
> And he should keep who can,"

to roll themselves into a sort of defensive ball. The mode of progression is doubtful. The animal may have had soft paddles, which were incapable of preservation, or it may have used the flexible power of its body to produce locomotion. Its eyes form a particularly interesting feature, both for their organization and the use that an eminent geologist, Dr. Buckland, has made of them, in explaining the condition of the seas in ancient geological eras. There are two eyes, each consisting of 400 compartments, or spherical lenses, which are so placed on the surface of a cornea, projecting conically upwards, that they all look outwardly from the animal's head. These, then, are raised, so that the animal, from its position at the bottom of the waters, can see all around without any hinderance from its own protuberant body; but their inward lines of vision do not cross each other, as that would have been an unnecessary waste of power—a striking instance of the combination of fertility and economy that Nature so often loves to present unto us. Wealth, not waste, seems ever her motto. But the trilobite has been a means of important special instruction to the geologist. It told Dr. Buckland that the air, the light, and the sea-waters of the incalculably distant eras when the trilobites flourished in such amazing profusion, were essentially as they are now. For, first, if the deep waters had been turbid, such delicate organs of vision would have been useless; second, had the atmosphere differed from its present condition, the rays of light would have been also affected to a different result, and then we should not have found, as we do find, the eyes of existing crustaceans agreeing with the older crustaceans in question; and, thirdly, as to light itself, it is certain that the mutual relations of light and optical vision were essentially the same then as now, because the essential organizations of the eye in both periods is the same—a happy instance of sound logical and geological deduction.

Already the distinction with which we are familiar, between the vegetable feeders and the Carnivora, or flesh-eaters, existed. The trilobites belonged to the latter class.

Condition of the Earth's Surface.—The chief characteristics of the surface of the crust during the existence of these systems are shown pretty clearly by the differences of the strata. The clay slates must have been compressed from fine clayey soil into their present state by waters of immense depth, but undisturbed by agitation. The sand and gravel of the grauwacke (or grey rock) reveal the effects of rivers, and of the action of the sea upon its shores. The lime of the Silurian rocks tells us of the long labours of the coral builders in raising the beds and reefs of limestone.

Igneous Rocks associated with the system.—Certain igneous rocks, not already mentioned, are generally associated with these aqueous rocks. They are serpentine, porphyry with greenstone, and other varieties of trap; the last we shall speak of in connection with the volcanic rocks. Serpentine derives its name from the contrasts of colour that it often exhibits, and which distantly resemble the skin of some serpents. It usually contains much magnesian earth. The term porphyry is derived from a Greek word, signifying purple, and is as old as the days of Pliny, when it was applied to a reddish rock, containing crystallized felspar, brought from Egypt, and used in ancient sculpture. It is now applied to all unstratified rocks in which detached crystals are imbedded.

Scenery of the Transition Rocks.—The finest examples of the scenery produced by the transition rocks—as those under notice are called by some

geologists, who consider them to occupy a place between the primary and the secondary—may be found in Wales, where, says Professor Phillips, supported by granite, and mixed with igneous masses, the slaty rocks of the English lakes rise to more than three thousand feet in height, and present a variety of outline, and intricacy of combination, which, in connection with clear lakes and considerable waterfalls, leave to Switzerland little superiority. But they also extend generally over the world, sloping away from the sides of its principal mountain ranges.

Uses.—Some of the uses of the rocks of this formation hardly need to be mentioned, they are so well known. The clay slates supply our schools with the popular instrument of instruction in writing and ciphering, and the roofs of our houses with the best of coverings. Slate boxes are also beginning to be used in our conservatories, and the slate itself for a variety of other ornamental purposes. The Silurian rocks contribute their help in the shape of flagstones for our street pavements; whilst the limestones furnish various ornamental marbles. But the metals they give us are still more important. Indeed, these rocks generally are (with the exception of the lead and ironstone of the carboniferous system) the richest of all others in this respect, as they include gold, silver, tin, lead, copper, &c., which are found in metallic veins traversing the clay slate.

SECONDARY STRATA.

The Carboniferous System: The Old Red Sandstone, or Devonian Rocks.

Name, &c., of the System.—This system includes the *Old red sandstone*, the Mountain limestone, and the Coal measures; from the latter the group derives its name—coal-bearing.

The Old Red Sandstone.—Upon the hollows and elevations of the undulating bed of the sea, around the ranges of the primary rocks, produced by the later phenomena of the first great geological era, the secondary strata began to be deposited. We have already seen how the matter to be deposited was ever in process of accumulation, from the wear of the substance of the primary rocks, and have spoken sufficiently of the various agencies and influences that operated to cause transport, deposition, and condensation. The entire thickness of the secondary strata, which comprise the Old red sandstone, the Mountain limestone, and the Coal measures, was small as compared with the thickness of the preceding rocks, and extended over much less space. The reasons are obvious; the one sprang from the causes at work through the whole globe, the second from causes that concerned chiefly only those parts of the primary rocks that were gradually exposed to atmospheric and other action. But, if of less depth and extent, they are of far greater variety and number, in the alternations of the lesser strata, and are, as a whole, greatly superior in all that concerns the development and support of organized beings. More and more, too, do they seem to approximate, in the circumstances of their formation, to the existing phenomena of external nature.

Name, &c.—It looks, at first, as though nature had receded, rather than advanced, in the earliest of the secondary strata, the Old red sandstone, a rock called old to distinguish it from another—the New red sandstone,

which is found above the Coal measures, denominated Red on account of the colour it exhibits in Devonshire, where it is most abundant; and hence the other name for the system—the Devonian. In this there is a decided decrease in the number of organic fossils, and what little vegetation had struggled into existence during the preceding systems is scarcely any longer to be found. The reasons appear to be that volcanic action was renewed with additional violence, which not only rendered the atmosphere and raised lands unfit for plants, but disengaged vast quantities of mineral matter—the peroxide of iron—which, being dissolved in the seas, rendered them less fit generally for the support of animal life. It is this iron which gives the peculiar colour to such large portions of the sandstone rocks.

Geographical Developments of the Old Red Sandstone.—The chief developments of the system in this country are in Devonshire (where it overlies the Silurian, and flanks the transition hills, as these again flank the primary ones), in Cornwall, Wales, Herefordshire, Shropshire, Worcestershire, Scotland. In Russia it extends over a space as large as Great Britain. The whole of the northern part of Scotland, from Cape Wrath to the north flank of the Grampians (which are granite and gneiss), have been described as consisting of a nucleus of granite, gneiss, and other similarly formed rocks, set, as it were, in a sandstone frame. The flat position of the strata partly causes this great surface extension: the earlier rocks are highly inclined. The thickness of the system in parts extends to ten thousand feet.

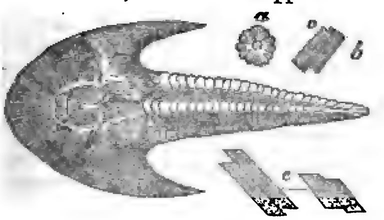
General Characteristics.—The sandstone is one of the most clearly developed of all geological systems. Where it exists in flat strata the scenery is uninteresting to the eye of the lover of the picturesque, though the farmer finds there a soil light and fertile; but where the sandstone rises into mountains there is a marvellous change. The hills are less high and abrupt than those previously formed, but are more lofty and varied than those of later date. There is a constant change of view. All the peculiarly charming incidents of a natural landscape—such as gentle undulations, deep glens, and woody recesses—arise, from time to time, to the eye of the traveller.

Composition.—The sandstone varies in composition from a fine-grained hard rock, that can be split into pieces for flagstones and tilestones, to a thick mixture or conglomerate of sand and pebbles, many of the latter being as large as a man's hand. Some calcareous beds are found in the system, consisting of an impure concretionary limestone, called by the country people cornstone. The colours include various shades, from red to grey, and from mottled purple and fawn to a creamy yellow. The mottled colour is chiefly observed in the sandy shales—a sort of imperfect sandstone—that belong to this system, and which are found alternating in thin layers with the sandstone. The whole are evidently littoral depositions—that is, they were deposited by the sea-shore. Many of the strata present to our eyes as plainly the ripple marks made by the waves of unimaginable centuries ago, as those which the wanderer by the seaside of to-day sees on the sand of the beach, and which are yet wet from the waters of the last tide. The lower, or grey series, in which the traces of the primary mica are to be found, is the sediment of calm waters. The sandstone and conglomerates owe their position and strata to the action of currents and aqueous agitation. The yellow beds were only deposited when once more all was quiet in their vicinity.

Vegetable Life.—There are no certain evidences of land plants during the Devonian era. Of marine ones fuci appear to have been the chief. These

must have grown in a higher temperature than exists where they are now found—a proof of the more general diffusion of a tropical climate in these remote geological periods. On this head we shall have more to say when we speak of the Coal measures.

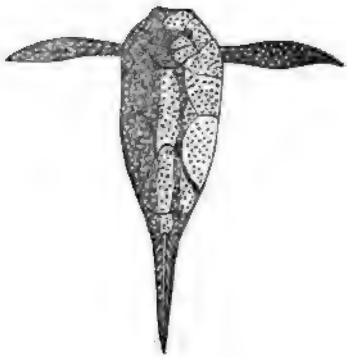
Animal Life.—No one even supposes there were any land animals during the Devonian era; all the things that breathed and moved had their home in the sea. Their general forms were not materially altered from those of the preceding Silurian era, but the species underwent a material change. Out of the eight hundred species comprised in the one era, only about one hundred passed on into the other. But to counterbalance this there was a large development of fishes, and a general advance in the character of existing organizations. Among the species that were thus preserved, the coral builders may be specially named. They are so abundant in Devonshire as to constitute entire strata—the beds of marble for which Babbacombe, Torquay, and Plymouth are famous. New species, of course, appeared—a monster trilobite, for instance, the Brontes, which was four feet long, and had lobster-like claws. The Cephalopods were now again largely represented, but with important changes in form. Fishes must have been plentiful in the Devonian seas. Upwards of a hundred species have already been reckoned. They were *all* cartilaginous—a striking feature of distinction from existing fishes, among which the bony-skeletoned are numerous, the cartilaginous few. These fishes were the destructives of their time, and kept down the too luxuriant population, as the Mollusca had done before them. Some are supposed to have been full thirty-six feet long. No less than nine genera of sharks have been discovered in the Russian Devonians. If we divide the Devonian fishes into the two orders, one of placoids—that is, having on the external covering irregular enamelled plates, laid edge to edge—and the other of ganoids, which possess regular enamelled scales overlapping each other, we find that one only of the orders, the first, had existed during the Silurian era; hence it is supposed that in that order the life of fishes may have commenced. Our engravings represent some of the more remarkable creatures found in the Old red sandstone. The annexed (the *Cephalaspis Lyelli*), is from a specimen in the possession of Sir Charles Lyell, after whom, we presume, it is named, and from whose *Elements* we copy the design. "Buckler-headed," these animals are called, from the strange shield that covers the head. To look at it, one would suppose the saddler's or cheesemonger's cutting-knife would be a still more suitable term. Strong as this creature was for resistance, he was weak indeed for active movement—the only organs suitable for that purpose being a range of very small fins.



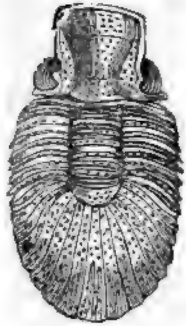
THE CEPHALASPIS LYELLI.—*a*. One of the scales of the head. *b c*. Scales from different parts of the body.

These fishes (the *Pterichthys*) derive their name from their wing-like appendages, which they are supposed to have erected when threatened by an enemy, in the hope, probably, of frightening him off by such an un-fish-like apparition; or, if that failed, of being used as a weapon of defence. The tail is presumed to have been the organ of motion. These winged fish are

as numerous in, and characteristic of, the Old red sandstone, as were the trilobites of the Silurian era. But trilobites remained and flourished in the



THE PTERICHTHYS.—Upper side, showing mouth.



THE BRONTES FLABELLIFER.

Devonian era also. We give an engraving of one (the *Brontes flabellifer*), in which, it is to be observed, the head is not quite perfect. Its outline should be wider and rounded. The parts missing in the fossil specimen here represented were, perhaps, softer or thinner, and so decayed, or were broken away.

Igneous Rocks associated with the Devonian.—The same igneous rocks that we have mentioned as being associated with the aqueous masses of the Silurian system, were also associated with the Devonian, with certain additions, such as amygdaloid, a trap rock, in which are imbedded *almond*-shaped minerals—hence the name. The "toad-stones" of our peasantry are varieties of amygdaloid, and have obtained their appellation from the marking and colours resembling those of a toad's skin. Granite is no longer found in intimate connection with the latest-formed rocks—a proof that the granite era—that is to say, the time when granite was being constantly formed below, and heaved up on high—had passed away.

Trap, and its connection with the system.—Without at present entering upon the subject of the volcanic rocks to which trap belongs, it is necessary to point out what is meant by the term. This is derived from the Swedish *trappa*, a stair, and expresses a peculiarity of the trap rocks, that they often rise in large tabular masses, one above another, like steps. When granite ceased to be upheaved, trap appears to have taken its place. And so we find that the rocks that upheaved the Devonians were trappean, or volcanic. The tremendous power that could thus raise immense portions of the earth's surface appears to have been quiescent during the time of the deposition of the Old red sandstone, and then, as though the time had come for which it waited, to have burst forth, scattering new mountain ranges over the earth, against the sides of which was to begin once more the work of material progress, in the deposition of yet a new strata—the mountain limestone.

Uses of the Devonian Rocks.—The uses of the Devonian may be thus summed up:—Tilestones for our house-tops, and flagstones for our foot-

pavements, from the lower strata; building stones, of moderate value, from the red and yellow strata; stones for macadamizing, from the trap; and agates and other precious stones from the amygdaloid variety of the latter. At the hill of Kinnoul, near Perth, there is a rock of this kind full of fine specimens.

The Mountain Limestone

Consists, in great part, of what was once life.—Perhaps there is no fact in geology so utterly beyond our power to realize even in idea the truth of, as the formation of the mountain limestone, which is found in our country eight hundred yards deep, almost its entire substance being the remains of animal life: we can in many instances trace distinct relics of shells, corals, and crinoidea to the extent of three-fourths of the mass. Need we say, after this, what an astonishing development of life must have characterized the present era, and left such evidences of itself?

Position, Geographical Distribution, &c.—The mountain limestone is found sometimes in beds, divided by layers of argillaceous matter, or of calcareous sandstone and shale, and surmounted often by the millstone grit of the north of England. At other times we find it flanking or even crowning the trap hills in masses of enormous size, when it has been likened to a coral reef surrounding the island which formed its base. Although generally the Coal measures are above the mountain limestone, beds of coal, of the harder and less bituminous kind, called anthracite, descend as it were below the great mass, and occasionally alternate with the various strata composing the limestone. On the other hand, the limestone seems to ascend beyond its own proper limits, and to alternate with the greater coal beds, and with sandstones, shales, and ironstones. The words "mountain limestone" are applied directly to the thick masses that are found beneath the Coal measures.

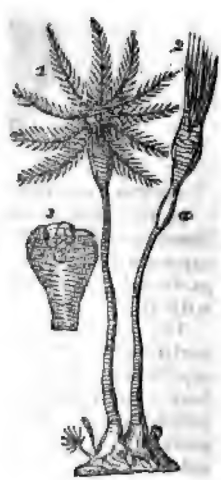
Caverns, &c.—A noticeable peculiarity of this limestone is its tendency to divide into rents, or "backs," as they are called, which are perpendicular to the line of stratification, and into other partings which are parallel with the same line. Caverns are frequent; the most magnificent caverns and grottos of the world are found in this rock—those of Derbyshire, for example.

Decided Development of Land Plants.—At last land plants begin to be visible in the earth, now represented by the mountain limestone; for it was unquestionably a terrestrial vegetation that was gradually transformed into the thin seams of coal found in the system. This fact, the great characteristic of the carboniferous group, will be better dealt with in detail when we reach the Coal measures.

Its Animal Life.—The animal life is still marine. The corals are now of large size, and exhibit a very marked advance upon those of previous eras. For instance, in the Silurian rock the corals were chiefly of a sessile kind, that is, sitting or supported in some way or other on or above the ground; but in the mountain limestone many of them are free independent animals, able to rove at their pleasure, and unlike any before or since existing.

The family of the encrinites or crinoids—the stone lilies—is very remarkable. "We may judge," says Dr. Buckland, "of the degree to which the individuals of these species multiplied among the first inhabitants of the sea

from the countless myriads of their petrified remains, which fill so many limestone beds of the transition formations, and compose vast strata of entrochal (expressive of the *wheel*-like joints of the stem of the animals) marble, extending over large tracts of country in Northern Europe and North America. The substance of this marble is often almost as entirely made up of the petrified bones of encrinites as a corn-rick is of straws. Man applies it to construct his palace and adorn his sepulchre; but there are few who know, and fewer still who duly appreciate the surprising fact, that much of this marble is composed of the skeletons of millions of organized beings, once endowed with life and susceptible of enjoyment, which, after performing the part that was assigned to them in living nature, have contributed their remains toward the composition of the mountain masses of the earth." Let us present a portrait of one of the members of this noticeable family: we cannot, perhaps, select a more interesting example than the *Apiocrinites rotundus.*



APIOCRINITES ROTUNDUS.

It is here shown as restored from the mutilated fossils, and greatly reduced from the natural size. In Fig. 1 we see the animal with its fingers open, ready to catch any of the smaller fry that might come within their grasp; whilst in Fig. 2 we behold them shut, while, possibly, the process of digestion is going on in the remarkable stomach revealed in Fig. 3. The thickened part marked *a* shows that an injury to the stem has been repaired. This animal was fixed at the bottom of the sea, but could reach a considerable distance around it, through the flexure of its wonderful stem, of which we will speak presently. Others were able to float singly through the water; and yet others were accustomed to attach themselves to floating pieces of wood, &c. The stem is composed of joints, often called wheelstones, and also St. Cuthbert's beads, as they were used in monkish times, upon strings, as beads for a rosary. Hence the lines—

> "On a rock by Lindisfarn
> Saint Cuthbert sits, and toils to frame
> The sea-borne beads that bear his name."

"Each of these joints presents a similar series of articulations, varying as we ascend upwards through the body of the animal, every joint being exactly adjusted to give the requisite amount of flexibility and strength. From one extremity of the vertebral column to the other, and throughout the hands and fingers, the surface of each bone articulates with that adjacent to it with the most perfect regularity and nicety of adjustment. So exact and methodical is this arrangement, even to the extremity of its minutest tentacula, that it is just as improbable that the metals which compose the wheels of a chronometer should for themselves have calculated and arranged the form of the teeth of each respective wheel, and that these wheels should have placed themselves in the precise position fitted to attain the end resulting from the combined action of them all, as for the successive hundreds and thousands of little bones that comprise an encrinite to have arranged them-

selves in a position subordinate to the end produced by the combined effect of their united mechanism, each acting its peculiar part in harmonious subordination to the rest, and all conjointly producing a result which no single series of them, acting separately, could possibly have effected."*

The shell-fish of the mountain limestone are also exceedingly numerous, and present many curious and gigantic forms; and we may conclude, from their superior development as regards their predecessors, that their ocean home had already experienced a more genial temperature. It is further clear that calcareous matter must have abounded in the water, to supply the material of which so large a part of their bodies consists.

a *b*

EUOMPHALUS PENTAGULATUS. *a.* Exterior view. *b.* Section showing chambers.

In this animal, which abounded in the sea during the era of the mountain limestone, the shell internally is divided into chambers, and the animal is supposed to have retreated at different periods of its growth from the compartment previously formed, and then to have cut off all communication with it.

The fishes of the era now grow to a gigantic size, and in some cases resemble reptiles so strongly that they have been called Sauroid fishes—from the reptile class, Saurians. Teeth have been found belonging to them four inches long—terrible instruments for the humbler neighbours which were destined to perish beneath their operation. We know the nature of these fishes' food perfectly, for their excrements—coprolites—have become fossilized; and we see mixed up with the latter fish scales and bones. And if there be something startling in this kind of familiar glimpse of the life of such distant eras, the feeling is increased when on close examination we can even perceive the unmistakable traces of the actions of the intestines, in the convoluted form of the coprolites.

The Uses of the Mountain Limestone are important. Valuable building stone is obtained from the sandstone beneath the mountain limestone, and from the millstone grit. The mountain limestone itself is our great storehouse for that most valuable article—lime. The encrinal beds already spoken of furnish an extremely pretty marble, in which, as in a picture, may be seen the various members of individuals of that interesting and abundant family. The ornamental spars of Derbyshire are well known: they belong to the mountain limestone. This rock also contains the principal lead mines of our country. With the lead, silver and gold in small quantities are not unfrequently associated.

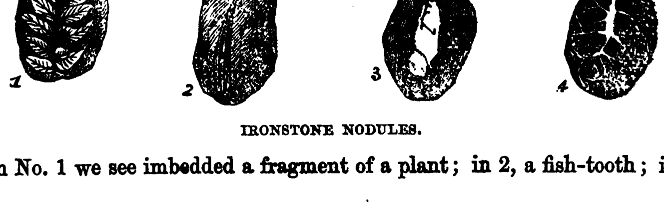
* Dr. Buckland's *Bridgewater Treatise*.

CHAPTER VII.

SECONDARY STRATA—THE COAL MEASURES.

Meaning of the Coal Measures.—Under this name we recognize that series of strata composed of coals, sandstones, shales (or mud), bands of ironstone, fire-clay, and impure limestone, which overlie the mountain limestone, and alternate with each other in irregular succession. Coal is the peculiarly distinctive and interesting feature of this series. At first it only appears in thin seams at the bottom of the coal measures, while the shales and sandstones, on the contrary, occur in thick beds. But as we ascend, the coal increases, and its companion minerals decrease, till about the centre of the "measures" we find the culminating point of the coal, for there it is at once found in the largest masses, and of the best quality. Above the middle it again begins to decrease, and once more the shales, but of lighter colour than the previous ones, and the sandstones prevail, until the next system is reached—that of the New Red Sandstone. A curious sort of regularity is often perceptible in the midst of the irregularities of the alternating strata. For instance, Professor Sedgwick tells us that at Cross Pits, in the Valley of Dent, Yorkshire, the coal seam under the twelve-fathoms limestone is divided by a band of clay, half an inch thick, into two parts, with distinct mineral characters; and the same coal seam, with exactly the same subdivisions, has been found in the mountains on the opposite side of the valley, at the distance of three or four miles, measured in a straight line. This seems to prove that a bed, not more than a fraction of an inch thick, was originally continuous throughout an area probably several miles in diameter.

The Ironstone of previous formations, it will be remembered, occurred in veins, or merely as a thin colouring matter diffused through the whole structure of the bed in which it is found; in the Coal measures we find it in the form of an argillaceous carbonate, massed in thin layers, from an inch or so up to a foot thick, and in irregular nodules, called septaria, from the nodules being divided into septa, or partitions. The formation of the nodules is worthy of remark. Each consists of a nucleus of the remains of animals and plants, such as fish-spines, coprolites, teeth, scales, leaves, &c., round which the ironstone has been deposited, till the whole took the forms here represented, and which we borrow from Mr. David Page's excellent *Rudiments of Geology*.



IRONSTONE NODULES.

In No. 1 we see imbedded a fragment of a plant; in 2, a fish-tooth; in 3,

a fossil coprolite, or excrement; and in 4, the internal divisions spoken of. These are formed by white carbonate of lime, which produces an effect somewhat resembling that of a beetle—hence the name among the peasantry, *the beetle stones*.

Varieties of Coal.—Coal is found in various states, and by comparing the whole of these together, the circumstances of its formation are made tolerably clear. We will briefly review the varieties.

Lignite, or brown coal, or wood coal (for it is known by all these names), represents the first step in the process of the conversion of vegetable into bituminous matter. There can be no doubt as to the origin of lignite, for the woody structure is still clearly to be seen in it. But our chemists have not been content with this evidence; they have made elaborate experiments, which show that if wood and vegetable matter are buried in the earth, exposed to moisture, and excluded from the external air, they decompose slowly, giving forth the while carbonic acid gas, thus losing some portions of their original oxygen, until, at last, the residue becomes lignite. It is by a continuance of this process of decomposition, and the accompanying discharge of carburetted hydrogen (the gas which we burn in our shops and streets), that Nature forms

Common Coal, which includes caking and cubic coal. Caking coal is so denominated on account of the tendency of its lumps to cake together during combustion—a quality doubtless owing to its highly bituminous nature. It contains forty per cent. of bitumen. This is the prevailing sort in the mines of Durham and Northumberland. Cubic coal is not so full of bitumen, and in breaking divides into cubical-shaped masses.

Cannel Coal is the most striking of all the strictly coal forms; and well we remember, in our younger days, when we lived in Devonshire, hoarding small pieces of it for the sake of its glossy, lustrous beauty. It makes most brilliant fires. Cannel coal contains about twenty per cent. of bitumen.

Jet is even more compact and lustrous. It is found in Saxony, and also in detached fragments in the amber mines of Prussia.

Anthracite.—Many of the fatal accidents that occur in mines are owing to the escape of various inflammable gases from mineral coal. These gases include carbonic acid, carburetted hydrogen, nitrogen, and olefant gas. After a long period of continual discharge of this kind, the common coal ceases to present its original characteristics, and is, in fact, transformed into anthracite, known also by the names of blind coal, from its burning without flame; glance coal, from its shiny surface; culm, &c. The word anthracite is derived from the Greek *anthrax*, charcoal, which expresses the distinguishing quality of the thing, for this kind of coal is little else than a mineral charcoal. In composition it is closely allied to the ordinary blacklead of our pencils. It is almost or entirely destitute of bitumen.

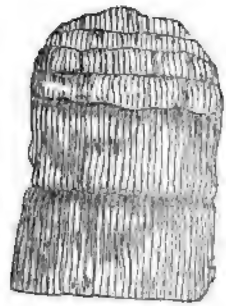
Formation of Coal.—While it is clear that the origin of coal is to be found in the decay and conversion of vegetable matter, it is a much more difficult question to determine the particular circumstances that contributed to its formation in the places where we now find it. Did the plants grow where the coal formed from them now lies? If not, how could such vast masses of vegetable matter have been brought together? Why, again, do we find the coal formations so continually interrupted by strata of shale or sandstones? And when we examine the nature of the plants of the coal formation, as evidenced by their fossil remains, we shall find reason to ask

another important question—What kind of climate could have existed in England when such plants grew here, if they did grow here? The two theories that seem best to account for the various phenomena we shall mention. The first of these is suggested by the knowledge of what is constantly going on in our own time at the mouths of great rivers, such as the Mississippi, which show us that enormous quantities of vegetable refuse, drawn away from the shores of the sylvan regions through which their waters pass, may be carried down to estuaries; there form into vast natural rafts, constantly increasing in size and density, until they sink to the bottom, and gradually become covered with a bed of sand or mud—the future sandstone or shale of some future coal measure, should other circumstances, similar to those that existed in former times, favour their conversion. It is very likely that this was one process of coal formation, if not the only one. Another is thus described:—Decaying vegetable matter forms peat; a subsidence of the earth beneath causes the peat to be overrun with the sea, and to be covered with sand or mud. Again, the land rises, new forests live and die, become peat, are depressed and covered with a similar layer of sand or mud; and this process, continually repeated, gives us, at last, the various alternating strata that we have already described. This theory receives some support from the fact that marine fossils are seldom found in the coal beds, which, if formed from decaying peat, would, of course, be essentially a terrestrial stratum; while they are abundant in the sandstones and clays that lie above and below the coal, showing that the coal stratum is preceded and followed by strata of an essentially marine character. The erect stems of trees, which are found with their roots fixed in the shale, in the natural place and position in which they grew, also show that they, at least, have not been transported from distant places.

A luxuriant Terrestrial Vegetation is, therefore, the great characteristic feature of the era of the Coal measures; and there are no topics in geological science of deeper interest than the nature of this vegetation, and of the atmospheric and other influences that caused it to spring up in such apparently sudden and boundless magnificence. Already the examination of the known fossils has resulted in our acquaintance with about eight hundred species, which are, or appear to be, chiefly gigantic developments of equisetums (or horse-tails), ferns, club-mosses, with us usually the lowliest of the vegetable family, but rising in the coal era to the most prodigious height, even to eighty feet; cacti, pines, and plants allied to the bulrush, cane, and bamboo, with a few palms, those princes of the vegetable kingdom, and tree-ferns. The fossils from which we learn these facts mostly appear in the shape of broken leaves or branches, pieces of trees, trunks, and in ripe fruits, which are not in their original clusters, but individually separate. There are no traces of flowers—none, at least, that are quite to be depended upon. Occasionally these plant fossils appear in extraordinary profusion, and of almost inconceivable loveliness. Dr. Buckland has described a scene of this kind in words worthy of it. He says:—"The finest example I have ever witnessed is that of the coal mines of Bohemia. The most elaborate imitations of living foliage upon the painted ceilings of Italian palaces bear no comparison with the beauteous profusion of extinct vegetable forms with which the galleries of these instructive coal mines are overhung. The roof is covered as with a canopy of gorgeous tapestry, enriched with festoons of the most graceful foliage, flung in wild

and irregular profusion over every portion of its surface. The effect is heightened by the contrast of the coal-black colour of these vegetables with the light groundwork of the rock to which they are attached. The spectator feels himself transported, as if by enchantment, into the forests of another world; he beholds trees of forms and characters now unknown upon the

SPHENOPTERIS ARTEMISIÆFOLIA.

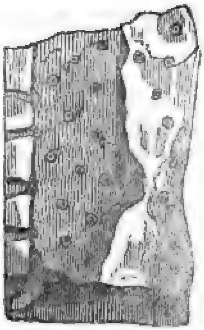


CALAMITES DUBIUS.

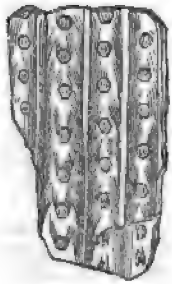
surface of the earth, presented to the senses almost in the beauty and vigour of their primeval life; their scaly stems and bending branches, with their delicate apparatus of foliage, are all spread forth before him, little impaired by the lapse of countless ages, and bearing faithful records of extinct systems of vegetation, which began and terminated in times of which these relics are the infallible historians." Ferns are by far the most abundant of the vegetable forms found in the Coal measures. About one hundred and thirty species have already been obtained from the coal, although the whole of the existing species indigenous to Europe amount only to about fifty in number. Our engraving above represents the *Sphenopteris artemisiæfolia*, which is one of the most elegant in form.

There are other plants, of an extraordinary aspect, found in great quantities in the Coal measures, and which botanists and geologists are alike puzzled to give the right place to. These comprise the *Calamites*, so called from the reed-like jointings of the stem; the *Stigmaria*, deriving their name from the stigmata or punctures that are found in its surface; and the *Sigillaria*, which have obtained their appellation from the graven appearance of the stalk. Look at the engraving of the *Calamites dubius*, and we need not wonder at the difficulty experienced in determining to what tribe such a strange-looking thing belongs. The interior of the Calamites was originally hollow, but has been filled up with the petrifying matter into which the whole has been converted. Some suppose these plants to be allied to the horse-tails, but it seems almost a libel on the graceful forms of the latter to put forth such an assertion. Others believe these to constitute a race of plants now altogether extinct. The Stigmaria, of which we present as a representative the *Stigmaria ficoides*, is the most common of all plants in the coal formation. Such parts as that

here shown were supposed to be mere portions of the extremity of the arms of a huge dome-shaped body, which divided into twelve limbs, each extending horizontally from the edge of the dome. For a long time this



STIGMARIA FICOIDES.

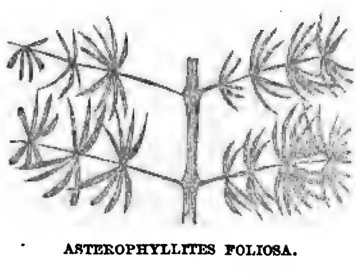


SIGILLARIA LÆVIGATA.

vegetable wonder baffled all conjectures as to its particular relationship with other plants, but at last it was discovered to be the root of the plant next mentioned—the Sigillaria—of which we likewise present a fine specimen above.

A large portion of the trees of the era belonged to this tribe, which grew to the height of seventy feet, with regular cylindrical stems, and without branches. The ornamental-looking studs show the places where the leaves were inserted. To the colliers of Newcastle and other places these fossil stems are but too familiar, under the name of coal-pipes, for they are a continual source of accidents. In mining they are often left in a vertical position in the masses of coal that extend overhead, and as they are very heavy, have no branches to support them, are broader at the base than above, and are merely supported by the cohesion of a thin layer of coal, which has replaced the bark, and is connected with the surrounding mass of coal, no sooner does this coating give way, than the column drops out of its bed, sometimes obliquely, sometimes perpendicularly, and kills or injures the workmen below.

There is one plant also very common in the Coal measures, which, were it only for its gracefulness, must be mentioned—the



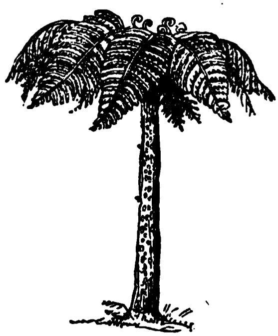
ASTEROPHYLLITES FOLIOSA.

It was probably allied to the Sigillaria. It is found in the Newcastle Coal measures. We need only to add to the foregoing enumeration the pines, which seem to be allied to the Araucarias, that have of late been so much spoken of in the gardening world, as among the most magnificent of existing coniferæ. As an interesting evidence of the resources of science, we may mention how the discovery was made of the nature of these trees. A gigantic tree trunk was found at Newcastle: there were no flowers or leaves: how were botanists to determine what tree it was? Some ingenious naturalists soon answered this query. They cut off very thin cross slices of the stem, polished them to the highest possible degree, and then submitted the slices to the microscope, when, lo! there were at once visible the peculiar "reticulations" which distinguish the cone-bearing trees, and the particular tree was soon decided to be an Araucaria.

No Grasses, Herbs, Shrubs, &c., in the Coal Measures.—In reviewing these names we perceive there are no grasses, no herbs, no shrubs, although all these now abound wherever vegetation flourishes. How is this? Are we to assume that they were all absent from the Flora of a time that was infinitely more rife than our own with the influences that develope vegetable life? The Coal measures, as we have seen, afford about eight hundred species; but our present vegetation contains at least eighty thousand! Do these numbers correctly illustrate the comparative meagreness of the one period, and the wealth of the other, as regards variety of life? The answer has been given by one of our most distinguished botanists, Dr. Lindley, who tried the following experiment:—He threw one hundred and seventy-seven plants into a vessel of fresh water. Among them were species that belong to the same great natural orders as those of the Coal measures, and others belonging to those orders most commonly diffused over the earth at the present day. His object was to learn whether the last would perish sooner than the first, and so afford an explanation of their absence from the Coal strata. In two years one hundred and twenty-one species had disappeared, and of the fifty-six that remained, the most perfect specimens were those of coniferous plants, palms, club-mosses, and ferns with their organs of fructification destroyed—in short, the very same generic kinds of plants that have been so long preserved in the Coal measures; and with regard to the ferns, in precisely the same state of partial and peculiar injury.

Had England, &c., at the time a Tropical Climate?—The tropical character of much of this vegetation is a startling phenomenon. Was there a tropical climate in England when the plants flourished that now form its coal beds? Was there a tropical climate in Newfoundland, which is now still colder than England? or in Melville Island, whose naked hyperborean plains make one shiver only to think of? All these places have their coal beds, and in all there must have once grown a rich and stately vegetation. In Melville Island the difficulty is enhanced by the geographical peculiarities of the sun's influence. For ninety-four days this luminary is never above the horizon, and for yet another hundred and four days he never sets. Puzzled by these difficulties, some have even asked the question—"Has the earth changed the position of its axis?" to which, we think, an answer may be given very decidedly in the negative. Dr. Lindley's explanation is, that we are probably deceived in the apparent analogy that exists between plants now living, and that grow only in tropical countries, and the plants of the Coal measures, and that the latter were not, therefore, after all, tropical; and where an analogy does exist, he shows that plants, belonging generally to a

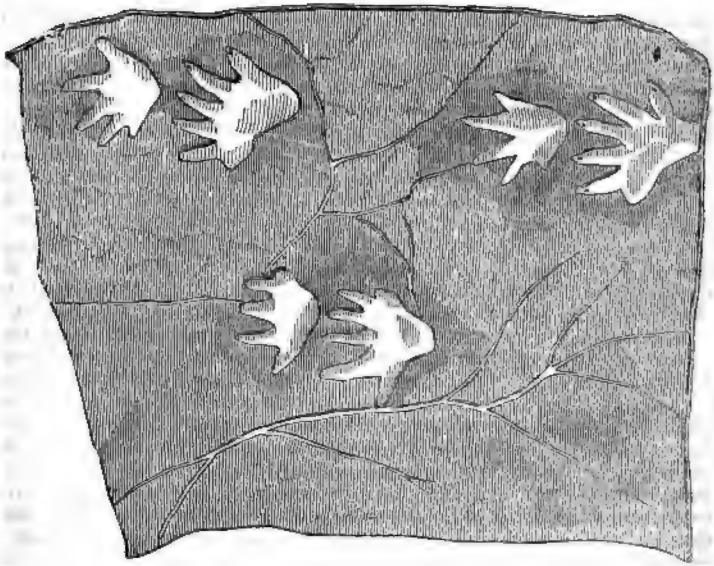
tropical clime, may yet have members of the family capable of enduring our severest winters. And he gives various instances in point. But all this while it seems to be forgotten that the ground temperature *must* have been very high all over the world, if the theory already developed, with regard to the earth's gradually cooling down from a state of intense heat, be true. And if such a ground temperature existed, of course there must have been a climate in some respects analogous to the hotter ones of our own era—probably, indeed, much more fervid than any one we now have experience of. The extreme abundance and gigantic size of the coral flora have been also attributed to the existence in the air of an extraordinary quantity of carbonic acid, the gas from which is derived the carbonaceous substance of all plants. M. Adolphe Brongniart, the author of this speculation, points, in corroboration of its truth, to the fact that there is hardly a trace of the existence of any land animals at the time this magnificent vegetation was in existence—the very excess of carbonic acid that nourished the one poisoning the air for the latter. It is by no means clear, or even probable, that the proportions of the atmospheric elements are always the same. Now, if the whole of the coal beds in Great Britain alone were again to be reconverted into carbonic acid, the effect would be to increase the proportion of the former to the latter from a thousandth part, as at present, to the eight hundred and fiftieth part. We may add, in conclusion, that the most eminent botanists, from Jussieu downward, have generally considered the coal plants to indicate the existence of a warm climate in their locality at the time they were growing. To sum up, therefore: the high ground temperature, and the excessive quantity of carbonic acid in the atmosphere, with possibly some minor but still important differences in the capacity of the latter, then and now, for the transmission of light and heat, seem, therefore, to furnish the true explanation of our finding such plants as tree-ferns in the coal of England, of Melville Island, and of Baffin's Bay—plants that now exist only in the very deepest recesses of the primeval forests of the torrid zone, breathing a damp and unchanging atmosphere, and living alone—true vegetable hermits, without even a neighbour or a parasite to while away the sultry hours. We must give our readers the pleasure of looking upon one of these extremely picturesque and oriental-looking plants in a better state than any fossil will admit. The following engraving represents a



LIVING TREE-FERN.

CHAPTER VIII.

SECONDARY STRATA—THE COAL MEASURES COMPLETED.

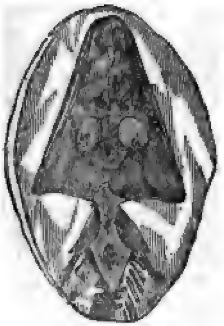


REPTILE FOOTPRINTS.

First appearance on the Globe of Land Animals.—With some such feeling as Robinson Crusoe gazed upon the unknown footsteps in the sand of his desert island did geological observers behold the mysterious marks shown in the above engraving, which were found impressed upon certain pieces of sandstone in some of the Coal measures of America within the last few years. Up to the time of these discoveries the animal life of the era appeared to be confined, as before, to the limits of the marine world, and that life on a greatly reduced scale, as regards abundance. Some estuary shells, some also belonging to the depths of the sea, a few species of fishes, chiefly Sauroids (found in the shales of the system), developed in certain cases to an enormous size—this was nearly all. As to the zoophytes and crinoidea, which were so abundant in the preceding mountain limestone, they had now altogether disappeared.

Some faint traces, it is true, had been lighted on at last, of the appearance in creation of air-breathing animals. Certain fossil beetles were found in

the coal-field of Coalbrook Dale; "a scorpion-like creature," a moth, and a land-crab were also presumed to be discovered. But our own time was to furnish new and most interesting additions. In 1844, Dr. King, of America, published an account of certain marks which he had found in the lower surface of slabs of sandstone, which slabs rested on thin layers of a fine unctuous clay. With equal discrimination and courage, he soon saw and announced to the world that they were the footsteps of a reptile that had walked over what was then the sands of some sea-shore. The doctor traced no less than twenty-three of these footsteps in the same quarry; and he considered that they were all left by one animal. Everywhere the marks showed a double row of tracks, the fall, in fact, at regular intervals, of a pair of feet. That this was an air-breathing, land-walking animal is considered to be proved by the depth of the impressions; under water, its weight would have been insufficient to have left such tokens of its presence. The cracks in the sandstone also show that the material had been exposed to the air and sun, and so had dried and shrunk. But as if to make quite clear and certain a fact so interesting in geological science, there was discovered the same year the skeleton of a reptile in the Coal measures of Rhenish Bavaria. This animal is supposed to have been related to the salamanders. In 1847 three other skeletons of animals, presumed to be allied to the crocodiles and lizards, were dug up at the village of Lebach, between Strasburg and Treves. The largest of these must have been three and a half feet long: its teeth seemed to have been of an advanced character in animal development. The smallest of the three is here represented half the natural size. The creature had evidently weak limbs, such as could serve only to swim and creep. Lastly, in 1849, the footsteps of a large reptile were discovered in the *lowest* beds of the coal formation at Pittsville, near Philadelphia. This, then, is certainly the oldest inhabitant of the reptile class yet known in geological history. And so far as present facts go, we may presume that this was the period of the first appearance of air-breathing terrestrial animals on the globe.



ARCHEGOSAURUS MINOR.

Coal-beds do not entirely cease with the era.—Although coal-beds are not unknown in connection with a later era, such facts are but special exceptions to the general rule, which confines their production to the carboniferous period. Over the greater part of the earth's crust, the conditions that were so favourable for the production of a luxuriant vegetation ceased with the termination of the era; and where we do find later coal-beds, we may conclude that those favourable conditions had there existed proportionally longer.

Proportions of actual Coal veins to the Coal Strata.—The depths of the coal, as compared with those of the other strata in which they are imbedded, are very small. In the north of England, for example, the entire series of strata are estimated to extend to about three thousand feet, while, if we reckon all together the respective thickness of each of the twenty or thirty coal seams they inclose, they will not exceed sixty feet. In South Wales the Coal measures are of far greater depth, reaching the extraordinary thick-

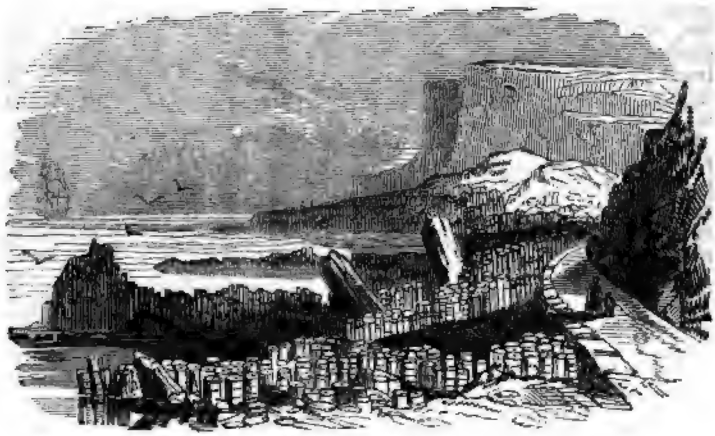
ness of twelve thousand feet, the result, says Sir Charles Lyell, "of fifty or even a hundred ancient forests buried one above another, with the roots of trees still in their original position, and with some of the trunks still remaining erect." We have more than once spoken of the awful ideas of time which geology gives us. Will any of our readers try to calculate for themselves, however roughly, on the preceding data, how long it must have taken to form the South Wales Coal measures—and then to estimate, if their fortitude will extend so far, the duration of the period that shall include the whole of the geological systems? They will then see that Geology is to time what Astronomy is to space. Both indicate the unfathomable. Both carry man to the extremest verge of his intellectual powers, and enable him, as it were, to look over trembling into the fearful abyss beyond. Both carry him at last in profound humility to God, whose help we require to enable us to stand fast amid such sublime phenomena.

Disturbances at the close of the period of the Coal Measures.—The period of the Coal measures evidently, then, closed in some abrupt manner. What were the causes? Doubtless volcanic action. Everywhere through the system we see the tokens of the presence of mighty disturbing powers. For instance, the normal position of the coal-beds appears to be that of hollow basins, following the curve of the bottoms of the seas in which their materials were deposited. Everywhere these basins are broken up into pieces, some of which have been cast up on edge, while others have been greatly depressed. There is a famous slip of this kind in the Newcastle coal-field, known as the "Ninety-fathom Hitch," where one part of the same original basin lies no less than 450 feet lower than the other part. But such hitches are known to extend to a thousand or twelve hundred feet. We shall see that all this is owing to volcanic action when we examine what are

The Igneous Rocks associated with the Coal Measures.—These comprise greenstones (popularly known also as whinstones), clinkstones, basalts, and trap-tuffs. All these belong to what is called, geologically, *Trap*. The trap rocks of this era are distinguishable from those of other eras by their darker colours, greater proportion of bitumen in their composition, and by the prevalence of basalts and trap-tuffs, containing limestone, sandstone, and shale in fragments. Their positions may be described either as arising from a movement originally of a disruptive elevating character, as exhibited in the hills of the Mountain limestone, and the rounded heights and irregular cones of the Coal measures; or as overlying, where basalt and greenstone occur, looking as though primarily poured forth in a liquid state; or where trap-tuffs are found strewed about with all the appearances of having been vomited forth by volcanoes in the form of ashes, dust, or cinders; or, lastly, as interstratified, a position frequently occupied by the trap rocks, and which implies that they were of volcanic origin, and had been gradually covered by sedimentary deposits.

The Trap Rocks of the Coal Measures.—Can these varying kinds of rock have all issued from the same volcanic masses of heated and fluid matter? Experiment gives the following answer:—All the trap rocks may be fused into one homogeneous mass, and then made to assume the varying forms we have already described by mere differences accompanying the process of cooling. Let us illustrate these facts by the formation of basalt, the most interesting of all the trap rocks. Put a number of round pellets of plastic clay or putty into a vessel; then gently press upon them, and they will take

the shape of five or six-sided columns, precisely like those of basalt in the wonderful natural structures of Staffa and the Giant's Causeway. The greatest known mass of basalt is that of the Deccan, in the East Indies, where it constitutes the surface of the earth for many thousand square miles. The traveller there often sees in the distance rising before him masses of broken columns, which induce him to believe he is approaching some important human structures, ruinous or otherwise. By the seaside such deceptive appearances are even still more common, especially where the columns are jointed, so as to seem built of separate stones. The dimensions



GIANT'S CAUSEWAY.

of these columns are sometimes most extraordinary. Some have been measured at Fairhead (the Giant's Causeway), which were found to be above a hundred yards high, while each of the sides was five feet broad. Was not the idea of the clustered columns or piers of our cathedrals originally derived from this source?

Distribution, &c., of Coal.—Coal is largely distributed over the world. Independently of its abundance in our own country, it is found in France, Spain, Germany, Sweden, Russia, Hindostan, Australia, New Zealand, China, the Persian Gulf, Melville Island, Nova Scotia, Cape Breton, the United States, Chili, &c., &c. While thus adding to the wealth of many localities, it by no means conduces to their beauty; for

The Scenery of Coal Districts is universally tame, level, bleak, and unfertile, as though Nature had been aware that, in extracting the treasures from below, we should only have deformed and abused her gifts of whatever might have been most beautiful in scenery above, by the many useful, but far from ornamental contrivances and arrangements for the exhumation and transmission of coal that are found at all times around coal mines.

The Uses of Coal, &c., need scarcely to be spoken of, they are so well known and appreciated. Our position as a nation speaks trumpet-tongued as to what we owe to coal. With it we fuse our metals, produce steam,

light our streets and shops, &c., with gas, warm our houses, and prepare our food. The annual consumption in these islands alone amounts, we believe, to about thirty millions of tons annually; and as though that drain were not sufficient, we export some three millions more. How long will our coal mines stand this enormous demand? They are far from inexhaustible. Many persons of scientific attainments have looked at this matter with some interest, not to say anxiety. The conclusion they come to is, that a supply may be depended upon, possibly, for two thousand years—a long period in the history of human civilization, as we understand it, yet but a mere span, when looked at from the geological point of sight. But we may be quite certain that science, every day growing more fertile of practical benefits to man, will, long before the expiration of that time, have found much superior modes of obtaining all that coal can give us. Even now we hear almost daily of new discoveries in heating, lighting, and motive power, that happily promise to supersede the three great branches of usefulness that make coal so precious to us at present.

We may add, in concluding this chapter, that among the many felicities of natural arrangement, perhaps we can nowhere find one more striking than that which the Coal measures present of the abundance, all nearly together, of the three articles, coal, lime, and ironstone, which are so indispensable to the production of the metal iron in a form fitted for the fabrication of tools, machines, and structures of all kinds.

CHAPTER IX.

SECONDARY STRATA: THE NEW RED SANDSTONE AND THE OOLITIC SYSTEMS.

Deposition of the New Red Sandstone.—Upon and around the ruins, so to speak, of the carboniferous system, when broken up by violent volcanic action, were gradually deposited, by the renewed activities of nature, the strata known under the above designation. These include Red Sandstone, Variegated Shales, of yellow, purplish, and green colours (the green arising from the presence of oxide of copper), and Magnesian limestones, of a creamy colour, existing in thick beds, and frequently presenting interesting forms of structure, resembling now honeycombs, now bunches of grapes, &c.

The Colour of the Red Sandstone involves some interesting points of study. The grains of which it is in a great measure composed are not red, but consist of white, rolled, quartz sand, surrounded "like varnish" with the red peroxide of iron. From whence could the immense quantities of iron be obtained that were sufficient to colour the sedimentary deposits in question to the depth, perhaps, of a thousand yards, and over large portions of the world? Some writers say it could not possibly have been derived from the disintegration of the older rocks (though this is denied by Sir C. Lyell, who says the hornblende or mica contains the oxide of iron in sufficient abundance), and that, therefore, we must look to volcanic action as the true agency, which, to this day, is constantly ejecting the mineral referred to.

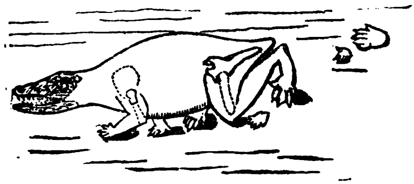
Salt forms a characteristic feature of this system of strata, and is found in various forms, as rock-salt and salt-springs; the latter issuing from the shales, which are often thickly impregnated with saline matter, or formed by the decomposition of the buried rock-salt in the lines of currents of water. Sir C. Lyell illustrates his views as to the formation of rock-salt by referring to an extensive plain in India, about the fourth part of the size of Ireland, called the Runn of Cutch, which is covered during a part of the year by the sea, and dry during the remainder, and then shows an incrustation of salt to the depth of an inch or two, caused by the evaporation of salt water. Now, supposing this plain to have sunk slowly for a great length of time, while the country still preserved the same generally horizontal direction, there would be, of course, a constant increase of salt by annual deposits, until even such depths might be attained as we find in the beds of salt of Northwich, in Cheshire, where there are two beds measuring respectively ninety and a hundred feet deep, and extending horizontally, it is supposed, for a great distance. Among the most interesting of salt mines are those of Salzburg, in Austria, in the heart of a mountain, and which have been worked from time immemorial. The rock-salt is found there of different colours, but chiefly blue, grey, and yellow. In one part of these mines the visitor finds himself in a kind of chamber, with a roof about seventeen hundred and eighty feet in circumference, perfectly flat, and bearing, without any central support, the entire weight of the mountain above. There are thirty or forty of these chambers, though not of the same gigantic size. The length of the mine exceeds two thousand yards; the depth is about three hundred and fourteen.

We do not, naturally, attach any ideas of a beautiful and luxuriant vegetation to soils saturated with salt, yet travellers give a charming picture of some of the salt lakes of Africa. Here is an example. The lake in question lies in the midst of an extensive plain, is of an oval form, about three miles round, and has on one side a sloping margin of green turf; while the other presents banks, more or less elevated and abrupt, covered with thickets of trees and succulent plants. At times, the whole of the margin of the lake, and much of its surface, are covered with a thick rind of salt, sprinkled over with snow-white crystals, the whole presenting the appearance of a frozen pond covered with the beautiful hoar-frost. This wintry aspect of the lake is strikingly contrasted with the luxuriant vegetation in which it is embowered, where woods of fine evergreens and elegant acacias are richly intermingled with flowering shrubs, and succulent plants of lofty size and exotic character—such as the plant of which the elephant is so fond, the *Portulacaria afra*, the tree crassula, the scarlet cotyledon, many species of aloes—some throwing out their clusters of flowers over the edge of the lake, others elevating their superb tiaras of blood-red blossoms to the height of twelve or fifteen feet; and, high over all, gigantic groves of Euphorbia, extending their leafless arms above the far-spread forest of shrubbery. The effect of the whole, flushed with a rosy tinge by the setting sun, is singularly striking and beautiful. Such lakes are supposed to be derived from salt-springs.

The Organic Remains of the New red sandstone system are singularly few, but highly interesting, as illustrating, both by their scarcity and their character, the nature of the great changes that took place in the sea and land when it was formed. The first thing that arrests our attention is the fact

that here, as in the Old red sandstone, we find the colour, arising from the presence of iron, to be connected, apparently as cause and effect, with a great destruction of animal and vegetable life, and which only slowly revived afterwards, as the conditions of soil and atmosphere became more favourable. Thus the thousand specific forms that existed in the carboniferous era were now reduced to about one hundred and sixty-six. Among these the corals alone dropped from about a hundred to fifteen; and of the latter only three or four are found plentifully. A single crinoidea, rarely found, alone represents that previously flourishing family, so characteristic of previous formations. The trilobite has gone altogether. These and similar facts cause the earlier part of the era (designated as Permean by some geologists) to be looked on as the close of the Palæozoic period—that is to say, of the period of the most ancient forms of existence. On this topic we must, however, observe in passing, that there is nowhere to be found in geology a period exhibiting a complete change. However great the latter may be, however attenuated the flow of life may become in passing from era to era, it never absolutely ceases in order to allow an entirely new creation to appear. This is so true in connection with the period under notice, that it would seem as though especial care had been taken to impress the truth upon all future observers; for, while a great decrease takes place, it is quite remarkable how the fossil plants, shells, fishes, and reptiles partake at once of the character of those that preceded, and of those that were to follow. Calamites, like those we have described as belonging to the Coal measures, are found side by side with the Cycadeæ, of which we shall have to speak in connection with the next system of strata—the Oolitic. Producteæ, like those of the Mountain limestone, are discovered in the Magnesian limestone, with Terebratulæ, similar to those of the lias and oolites of the said Oolitic formation. And while old forms are dying out, new ones are also appearing. If the fishes of the genus Palæosaurus now are found for the last time, the oviparous quadrupeds, Protosaurus and Phytosaurus, now first make their appearance.

The Footmarks of Animals that have, so far as we know, left no other record of their presence on the globe, now become numerous, and proportionably interesting. They are found in different countries, and as representing very different classes. Some were found in the quarry of Corn-cockle Muir, Dumfriesshire, where the sandstone, which was formerly sea-beach, lies at an inclined angle of thirty-eight degrees. Up and down this slope the footmarks are traced, as though they belonged to an animal which had daily passed to and fro in its visits to the sea. Other marks were observed in the Storton quarries, on the west side of the Mersey, Cheshire, imprinted on fine thin beds of clay, ranged one above another, separated by beds of sandstone. Each of these thin seams of clay had probably been, at one time, the surface of the ground; then submerged, a sand deposit left on it, again raised, and a new clay surface formed, and so on repeatedly. The animals here referred to have been determined, after a long and rigorous investigation, to belong to the Batrachians, or frog family. One great



LABYRINTHODON PACHYGNOTHUS.

living natural philosopher, Professor Owen, has shown how he conceives such footprints to have been made, by a restoration of the kind of animal that made them.

It is in the United States that these footmarks have been found in the greatest variety and number. There, in the rocky banks of the Connecticut, some thirty-two species of bipeds, and twelve of quadrupeds, have been discovered. The tracks have been found in more than twenty places, extending over eighty miles of territory, and including above two thousand distinct impressions. Many of these are the footprints of *birds*, belonging, it is supposed, to the families of *Waders* and *Scrapers*. The size of some of the bird footprints greatly exceeds that of the largest living ostrich, and certain naturalists were at first incredulous as to their having been really made by birds; but recent discoveries of gigantic birds in New Zealand have entirely removed this difficulty, even acknowledging it to be one.

Rain-drops of Remote Eras.—It almost sounds like an incident from a fairy tale to say that we can, by the means of geological science, raise before the mental eye facts of the most ordinary daily character, in connection with periods too remote for us even to calculate in years—yet that we can do so is certain; for instance, we can not only see, as it were, the very rain falling on a day belonging to such a period, but tell from what direction it came. On certain slabs of sandstone—the Greensill, near Shrewsbury—the hollows formed by rain-drops are clearly to be recognized, and their rims being raised on one side, shows that they had fallen from a slanting shower, as well as the direction of the slant.

The Shell Limestone, or Muschelkalk Fossils.—The strata known as Muschelkalk (shell limestone), which is missing from the system in England, but which is found richly developed in Germany, is especially remarkable for the fossil reptiles discovered in it, belonging to the marine saurians. Pretty monsters some of these were! There was the Ichthyosaurus, or Fish-Lizard, some thirty feet long, with the form of a fish, and some of the qualities of more highly organized animals. It had a fish's tail, crocodile's head, paddle-fins like the whale, a skin resembling that of the cetaceous

THE ICHTHYOSAURUS.

animals (whale family), and its breast-bone resembling in structure that of the Australian duck-rat. Its horrid jaws expanded to the extent of seven feet at a stretch; and, while such provision was made for dealing with its prey, the eye seemed constructed on a scale of equal efficiency for showing where the prey was to be found, for it had a socket eighteen inches in diameter.

The Igneous Rocks, associated with the New red sandstone, are chiefly green-

stone, found in the form of dykes, which have been driven upward through the Old red sandstone, Coal measures, and Magnesian limestone.

Localities.—The system is largely developed in the central districts of England; also in France, Germany, Poland, the flanks of the Alps, the United States of America, &c. The series of strata is found peculiarly rich in Germany, where one member of it—the Muschelkalk—is found above the Magnesian limestone, and below the lias of the Oolitic formation; while, as we have said before, it is altogether absent in England. At Thuringia, in Saxony, the Magnesian limestone is found so highly developed as to be deemed by geologists peculiarly its "classic ground."

The Scenery of the New Red Sandstone is not particularly attractive. Pleasant, but flat, might be said of it. The rounded terraces and eminences of the Magnesian limestone, with their thick and verdant sward—the level expanse and fertile surface soil of the red sandstone—and the wide marshes formed by the shale, are the chief elements of such variety as the landscapes of this system afford.

Uses.—Reduced to quicklime the Magnesian limestone becomes valuable for mortar and manure. It also furnishes the magnesia of the chemist's shop. Its more dignified use is that to which the finest specimens are appropriated, namely, for the erection of such piles as the New Houses of Parliament; the Magnesian stone from Bolsover Moor being thus used. Some of the slaty limestones are used by lithographers, the best German stones being obtained for this purpose. The marls afford us their useful contribution in the shape of gypsum for manure.

The Oolitic System.

Deposition of the Oolitic System.—Again, as if to make up for the destructive agencies of the New Red Sandstone system, stupendous restorative ones were at work in the period that followed; and, in consequence, that period, the Oolitic, is characterized by an abundance and high development of life not unworthy of comparison with the luxuriance of being already noted in the carboniferous era. The material preparations for this increase may be briefly noted. By fresh upheavings and submergings of the earth's crust, the red sandstones gave place to yellow calcareous grits; the variegated and salt-impregnated marls to blue clay, mixed with iron pyrites; the magnesian rocks to oolitic limestones, whose peculiar texture gives name to the whole system. Sir C. Lyell thus describes the origin of this system:—"We must conceive a sea in which the growth of coral reefs and shelly limestones, after proceeding without interruption for ages, was liable to be suddenly stopped by the deposition of clayey sediment. Then again, the argillaceous matter, devoid of coral, was deposited for ages, and attained a thickness of hundreds of feet, until another period arrived, when the same space was again occupied by calcareous sand, or solid rocks of shells and coral, to be again succeeded by the recurrence of another period of argillaceous deposition."

Meaning of the Term.—Oolite is derived from *oon*, an egg, and *lithos*, stone, in reference to the novel structure of the stone in question. This consists of rounded calcareous particles, varying in size from as large as marbles to as small as millet seed, and the larger of which contain broken shells. The particles are probably of chemical origin.

Division of the System.—It consists of three groups—the Lias, the Oolite proper, and the Wealden clay.

The Lias, a corruption of layer, is known generally by the dark hues that prevail among its strata, and which comprise dark clayey limestones, whose fine stratification shows it to have been deposited in tranquil waters; bluish clays, the predominant member of the group, and which occur interstratified with layers of jet and other coal, ironstone, and limestones; and lastly, shales, occasionally impregnated with salt, sulphates of magnesia, and soda, whilst many abound in iron pyrites and bituminous matter. Parts of the sea-cliffs of Yorkshire, thus composed, are said to ignite spontaneously, and to burn for several months together.

The Oolite Proper includes, besides oolitic limestones, calcareous conglomerates of sand, lime, and shells; also yellowish sands and calcareous clays.

The Dirt bed occurs above the oolite proper, and is found in Weymouth and other places. This is a thin stratum of soil, just like the surface soil of our own time, and full of remains of tropical trees.

The Wealden Clay occurs highest of all in the series. It derives its name from the Wealds of Kent and Sussex, where it is largely developed. The dry land, forming the dirt bed just mentioned, is supposed to have afterwards become an estuary, including the whole south-east province of England, and which formed the mouth of some river belonging to the grandest scale of river, such, for instance, as the Mississippi. It has been surmised that this particular river may have flowed from a point not nearer than the site of Newfoundland, with, of course, banks extending all the way. How the Wealden clay was formed in this estuary Sir H. de la Beche thus describes:—Much calcareous matter was first deposited, and in it were entombed myriads of shells, apparently analogous to those of the Vivipara. Then came a thick envelope of sand, sometimes interstratified with mud; and, finally, muddy matter prevailed. The solid surface beneath the waters would appear to have suffered a long-continued and gradual depression, which was as gradually filled, or nearly so, with transported matter. In the end, however, after a depression of several hundred feet, the seas again entered upon the area, not suddenly or violently, for the Wealden rocks pass gradually into the superincumbent cretaceous series, but so quietly that the mud containing the remains of terrestrial and fresh-water creatures was tranquilly covered by sand, replete with marine exuviæ.

Contents of the Wealden Group.—It includes beds of dark blue clay, with ironstones in nodules, argillaceous limestone, impure oolites, and sandstone deeply impregnated with iron; in fact, oxide of iron is diffused through—and to a certain and varying extent colours—the whole group.

Animal Life.—Among the many fossils found in the Oolitic systems it is difficult to make a selection—they are so numerous, and present so many features of high zoological and geological interest. We find zoophytes approaching those of our own era; Crinoidea, which are few and dwarf compared with their predecessors; Star-fishes; Sea-urchins; Shell-fishes, including Ammonites, Belemnites, Gryphæa, Trigonia, and Ostrea; Annulosa like the common earth-worm; Crustacea, including the king-crab, which—appearing at the very time that the trilobite (the animal it most nearly resembles) disappears—forms one of those links by which Nature loves to bind all her works together in an unbroken series; Insects, like the beetle and dragon-fly,

which were discovered in the slaty limestones of the Oolite proper at Stonesfield, in England; Fishes, presenting the *regular* enamelled scale that marks the Ganoid order, and the unequally divided tail, a feature which is confined to a few of our existing fishes, but was universal with the fish of the magnesian limestone and all earlier formations; Sauroid reptiles, like existing crocodiles, tortoises, and turtles, but differing widely in their habits; Flying Lizards; and lastly, Mammalia, now first appearing on the surface of the globe, in the shape of animals allied to the Opossum family. Of all these the Sea-urchins and Shell-fish—as Ammonites, Belemnites, Gryphæa, &c.—the Sauroid reptiles, the Flying Lizards, and the Mammalia, form the most characteristic animals of the era. The Belemnites (allied to the cuttle-fish) had an ink-bag with which to discolour the water, and so conceal it from enemies. Some of that very pigment has been used in our own times by an artist to depict the fossil Belemnite itself! As to the Sauroid reptiles, the oolitic eras may be called *their* era—so abundant are their relics in the lias and superincumbent strata. The flying lizards form, perhaps, the most extraordinary of all the creatures that geology makes known to us. They were about the size of the cormorant, but had bat-like wings extended upon the fore-finger, with which to fly. The ichthyosaurus, already spoken of in connection with the German shell limestone, now also occurs in the lias of this country. But most interesting of all are the Mammalia, the first of the series of which Man was to be the last. Our earliest glimpse of the animals in question occurs in the Stonesfield slate, where several specimens of jaw-bones have been found, and which have been compelled to give up the secrets of their past life in answer to the potent spells of modern science. They are now believed to be the remains of marsupialia, to which belong the kangaroo, and other animals that now characterize the Australian zoology. It is a remarkable circumstance that this animal is not the only thing that suggests a connection between England as it was, and Australia as it is. In and around the latter are still found various animals and plants that are closely allied to many of both that were rife in the oolitic and other early periods. Among animals, for instance, Cestracion, Trigonia, Terebratulæ; among plants, the Zamia, Tree-fern, Araucarias, and Cycadeous plants. The latter form the most characteristic feature of the vegetation of the oolitic period; their stems, fruit, and leaves are found in great abundance in the fresh-water Wealden, intermingled with stumps and prostrate trunks of trees. They form a tribe intermediate as it were between palms and conifers, having a tall, straight trunk, and a crown of magnificent foliage.

The Igneous Rocks associated with the Oolitic system represent, apparently, the last efforts of the trappean era. The volcanic forces now suffice to send up occasional outbursts of trap-tuff or intersecting dykes of greenstone, and that is all.

Localities and Scenery.—The Oolitic system is very fully developed in England—especially in the eastern sea-coast from Yorkshire to Dorset—in France, Westphalia, Northern India, Africa, &c. The contour of such countries is that of gentle undulation, formed by rounded limestone heights and intervening valleys of clay.

Uses.—From the lias limestone, deeply impregnated with iron, there is formed, after burning, a lime that sets under water. Lithographers' stones are also obtained from the lias. Alum is formed by burning the lias clay that contains iron pyrites; these give forth sulphur, which, with oxygen -

from the air, and alumina from the shales, form alum. In the upper beds of oolite, fuller's earth is found in beds of great depth. Some Oolitic sandstones, such as those of Bath and Portland, make excellent building-stone; and others, ornamental marbles. Lastly, the common paving-stones of London streets are drawn from the Purbeck quarries of the Wealden clay.

Revival of the Oolitic Period.—We cannot better conclude our present chapter than with a passage of rare eloquence devoted to the period we have just reviewed. "The imagination," says the author of the *Vestiges of Creation*, "eagerly aspires to picture the world of the Oolitic era, when there were scarcely any living creatures of more exalted character than reptiles. There were then vast tracts of dry land, as now; their surface bore a luxuriant vegetation of no mean kind. The meteoric agencies, the rise and fall of tides, were common phenomena of that time, as of the present. Day after day, through long-drawn ages, the sun passed on his course. Night after night the sparkling garniture of the sky looked down on this green world. But a being of superhuman intelligence, coming to examine our globe, would have seen all this existing only for fishes, and still humbler creatures in the sea; and for reptiles, insects, and perhaps a few birds, and still fewer opossums, upon land. He would have beheld the tyrant sauria pursuing their carnivorous instincts upon the wave, upon the shore, and even in the air; huge turtles creeping along the muddy coasts; still more huge megalosaurus, traversing the plain; and with all this, the air filled with multitudes of insects. But no flocks would have met his eye upon the mountains, no herds quietly roaming in the valleys. He would encounter no tiger or elephant in the jungle. None of the smaller mammalian quadrupeds—as the dog, the genet, the hedgehog, the hare, the mole—would have presented themselves. And not only were no human beings to be seen, but our supernatural visitant would know that this scene must lie spread out, in perfect capability for their reception, during whole millenniums, before such beings were to exist; the stream flowing and glittering in the sun, but not to cheer the eye of man; the season passing, but not to yield its fruit to him; the whole jocund earth spread out in unenjoyed beauty, as yet unwitting of the glory and gloom which human impulses were to bring upon it. How strange to reflect on the contemplations of the supposed visitant! What a vast void! What a stretch of time before there was to be even a commencement to its proper filling! And yet the certainty that in good time, in the ripeness of the plans of the mighty Author, the higher animals were to come, and among the last, the creature of creatures—who, in his infinity of device, was to turn it all to his use—the historical being of the world!"

CHAPTER X.

SECONDARY STRATA—THE CRETACEOUS, OR CHALK SYSTEM—TERTIARY STRATA.

Deposition.—We have now arrived at the last (or uppermost) strata of the secondary formation. In Europe these were deposited in the same sea—

or oceanic—basins as their predecessors, though in America it was not so. Generally we find the Chalk strata overlying the Wealden, or, where that is wanting, the Oolitic.

The name Cretaceous is derived from the Latin, *creta*, chalk, and was applied to the strata in question in consequence of the chalk being the highest member in those parts of Europe where the system was first studied.

Structural Changes in the Sandstones, &c.—The chief changes that now took place in the material of the earth's crust were the conversion of the sandstones into loose sand—known as the green sand—of the clayey beds into a marly clay, called galt—and of the limestone into chalk. These three, therefore—green sand, galt, and chalk—form the main bulk of the Cretaceous system.

The Green Sand, or Shankland, as it is sometimes called, consists of a triple alternation of sand, clay, and sand. The distinctive colour is owing to the presence of silicate of iron. Sometimes, however, a yellowish tint prevails. Ochre, fuller's earth, and cherty* beds are occasionally found in the green sand. This series is altogether absent from the chalk group of the north of England.

Galt forms a stiff, blue, and very dark-coloured clay, abounding in shells, which are often remarkable for their pearly lustre. The American Chalk system has no galt. The beds of galt are not very thick. They occur with alternations of green sand, and contain balls of clayey ironstone and iron pyrites. The reddish colour often found in galt is owing to the presence of iron.

Chalk, the predominant, is also the most interesting feature of the group. It consists of carbonate of lime—generally of a pure white, but sometimes of a red or dusky grey colour. It is often found in a hardened state, and crystallized almost like marble. These qualities are attributed to the action of the igneous subterranean agencies. This theory has, to a certain extent, been proved by experiment. When pounded chalk is inclosed in an iron tube, and subjected to great heat, it becomes similarly hard and crystalline. This, like the green sand, is often subdivided into upper and lower beds. The upper chalk beds are of a compact texture, a dusky white hue, mixed with green grains, and containing but few flints. The lower ones are much softer, more calcareous, and contain nodules of chert, and regular layers of flint—the latter giving almost the only indications afforded by the chalk beds of regular stratification. The formation of flint and of chalk is among the more interesting problems of geology.

Flint.—The upper chalk beds form the true native place of this mineral, where it occurs in regular layers, consisting either of nodules or flat tabular masses, extending to a great distance in certain parts, as in the chalk cliffs east of Dover, where a flint bed, two miles long, is found. The nodular masses vary in size from an inch or so up to a yard. Flint consists essentially of a mass of grey or black silex, coated over with a white cherty crust, and containing, not unfrequently, cavities lined with calcedony or crystallized quartz. Who would suspect that a mineral bearing these characteristics is, after all, little less than a mass of extinct life? Yet this is, in all probability, the case. Most flints inclose remains of sponges, echinites, &c.

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* Chert is a mineral nearly allied to flint and calcedony, but less homogeneous and simple in texture.

These organisms were the nuclei round which the particles of silex accumulated. But whence these particles in a substance—chalk—so different? The great animalculæ observer, Ehrenberg, suggests that it is the remains of the flinty coverings of microscopic creatures, whose shells he has, in other cases, discovered in their original condition. This is the more probable from the facts discoverable in the study of the formation of the

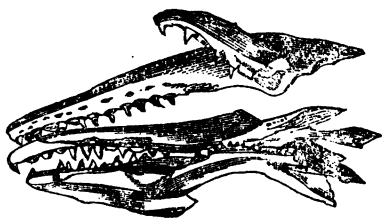
Chalk.—It had often been suspected that chalk might be of animal origin, notwithstanding the fact that no traces of animal remains could be discovered in certain chalk masses; for, in the first place, it consisted of pure carbonate of lime, such as would remain from the decay of corals, &c.; and secondly, such fossils, when half decomposed, seemed to be also half changed into chalk, or a something greatly resembling it. But certain discoveries have made this speculation all but a certainty. A traveller, Lieutenant Nelson, has shown that there are several lagunes of the Bermuda islands which are surrounded by coral reefs, and which have, at their bottom, a soft, white, calcareous mud, evidently formed of the decay of various tribes of corals. When dry, this mud is scarcely, if at all, to be distinguished from chalk. Mr. C. Darwin has observed similar facts in the Pacific coral islands. He believes that much of this white mud has passed through the bodies of worms, which have everywhere bored through the coral rocks. Other portions, he thinks, have passed similarly through the bodies of fish, which may often be seen browsing, in great numbers, on the living corals—just like so many quadrupeds in a field on the growing grass. Their intestines have been found filled with impure chalk; and thus we get an explanation of the bodies formerly known as the cones of the larch, but which were subsequently found to be the excrement of fish. Ehrenberg, however, goes much further. He states that chalk is composed partly of inorganic particles, and partly of shells of such inconceivable minuteness that a cubic inch of chalk would contain above ten millions of them! The chalk of the north of Europe contains much more inorganic matter than that of the south—the latter being often composed almost entirely of what was once alive! He has succeeded in discovering the character of many of these minute creatures; some belong to the nautilus family. The same observer has found microscopic sea-plants in the chalk.

The Organic Remains generally show that they were deposited at the bottom of seas or oceans, for no recent formation is so destitute of terrestrial organisms. Fragments of ferns, cones of coniferous trees, cycadeæ, strips of lignite (wood-coal)—such as is found in the lower chalk near Rochelle, in France—are the more noticeable of the vegetable terrestrial remains of the period. Many pieces of wood have also been discovered, both in Europe and in America, drilled full of holes by the Teredo, thus showing that they had long drifted about in the ocean, and that the conditions of life were, to a certain extent, somewhat similar over great portions of the globe.

In other respects the fossils of the Chalk system are very rich. As Sir H. de la Beche observes, "Organic remains are, in general, beautifully preserved in the chalk; substances of no greater solidity than common sponges retain their forms; delicate shells remain unbroken; fish even are frequently not flattened; and altogether we have appearances which justify us in concluding that since these organic exuviæ were entombed, they have been protected from the effects of pressure by the consolidation of the rock

around them, and that they have been very tranquilly enveloped in exceedingly fine matter, such as we should consider would result from a chemical precipitate."

As all the ordinary and more noticeable orders—though of very different genera—of the sea inhabitants existing up to the Cretaceous era, have been found in the chalk formation, with the exception of the whale family, we need not recapitulate them, but content ourselves with a word or two upon the more special features of the zoology of the latter:—First, as to the fishes, which had existed up to this period in two orders only, the Ganoids and Placoids. Now these orders decline, and fishes of a higher organization appear, resembling those which exist in our own time—that is to say, bony in structure, with corneous scales. The reptiles contribute the most interesting additions to the growing zoological wealth. Among these occur the Mosasaurus, which was first made known to us by the discovery of a perfect head, near Maestricht, and hence the name given to the creature of "The Great Animal of Maestricht." This was thought, at first, to be a crocodile, then a whale; but Cuvier has proved that it was a great marine reptile, nearly allied to the Monitors. We may here mention one of the facts that belong to the glories of science, and which contribute wonderfully to its support by showing us how much faith can safely be reposed in its statements. Cuvier asserts of this animal that before he had seen a single vertebra (joint of the back-bone), or a bone of any of its extremities, he was enabled to announce the character of the entire skeleton from the examination of its teeth and jaws alone; nay, even from a single tooth! When the Mosasaurus first appeared, some of the largest creatures that roamed beneath the deep waters were saurians of gigantic stature, which controlled the excessive increase of the then extensive tribes of fishes. From the lias upwards, to the commencement of the chalk formation, the Ichthyosauri and Plesiosauri were the tyrants of the ocean; and just at the point of time when their existence terminated, during the deposition of the chalk, the new genus Mosasaurus appears to have been introduced to supply for awhile their place and office, being itself destined in its turn to give place to the whales of the tertiary period. No saurians of the present world are inhabitants of the sea, and the most powerful living representatives of this order, viz., the crocodiles, though living chiefly in water, have recourse to stratagem, rather than speed, for the capture of their prey. But the Mosasaurus was so constructed as to possess the power of moving in the sea with sufficient velocity to overtake and capture large and powerful fishes. Thus it teeth and jaws were enormous; and the animal itself was probably not less than five-and-twenty feet in length, although the longest of its modern congeners does not exceed five feet. The head of the Mosasaurus, here represented, measures four feet in length; that of the largest Monitor does not exceed five inches. The animal resembled the Iguanas in having teeth apparatus so placed in the mouth as to act as barbs, preventing the escape of the prey. The vertebræ were fitted with a ball



THE MOSASAURUS.

and socket-joint, so as to admit easy and universal flexion. The tail was flattened on each side, but high and deep in the vertical direction, like that of the crocodile, so as to form an oar of immense strength to propel the body by movements analogous to those of sculling. Instead of legs the Mosasaurus had four large paddles, like those of the whale, which were probably used to enable it to rise to the surface for respiration.

The specimen from which the cut is taken was discovered in 1700. At the capture of Maestricht by the French it was taken away from that town, and deposited in the Museum at Paris, where it now is. Our readers may judge of the value attached to it, when they are told that the French artillerymen were directed not to point their artillery towards that part of the town where the precious relic was deposited.

The American chalk formation also gives us a new gigantic reptile, the Saurodon, so called from the lizard-like character of its teeth. Bird footsteps are here again discovered, as, for instance, in the slate of Glaris, in Switzerland, a group corresponding with our galt; also in a chalk bed near Maidstone. They belong, it is supposed, to birds of the long-winged swimmer family, and were of the size of the albatross. Lastly, we may mention that individuals of the monkey tribe—the highest below Man, whom we are now fast approaching—are discovered in the chalk; a fact that, taken in connection with the appearance of the neighbouring tropical plants, the cycadeæ, shows that during its deposition a tropical climate prevailed.

Igneous Rocks associated with the System.—The Cretaceous group generally has suffered but little from volcanic disturbance, though, where the latter has happened, the effects have been on a magnificent scale, as in Ireland, where eruptions of basalt and other allied rocks have burst through and spread over the chalk to an enormous extent. The Giant's Causeway, already spoken of, presents one of the finest examples of this character.

Local Distribution.—In England the chalk group extends in a long stripe from Kent to Yorkshire, and occupies nearly the whole of the south-eastern parts, filling up the hollows left by the lias and oolite. Salisbury Plain is occupied by the upper chalk beds. The cliffs of Dover belong to the chalk formation. It extends also into the north of France, thence onward into Germany, Scandinavia, and Russia, and covers a vast area in the United States.

Scenery, &c.—The chalk is often covered with the tertiary strata, but it is also often denuded, or left bare. Independently of the colour—which becomes every here and there perceptible in chasms, &c.—the chalk districts are easily recognized by the smooth-flowing outlines of the hills and valleys, forming, in many parts, a scene of charming undulations, well known to most persons under the denomination of "wolds," or "downs." The contrast between the upper and lower members of the group, in their effects upon scenery, is very striking. While we find one writer describing the chalky southern downs of England as "covered with a sweet, short herbage, forming excellent sheep pasture, generally bare of trees, and singularly dry, even in the valleys, which for miles wind and receive complicated branches, all descending in a regular slope, yet are frequently left entirely dry, and what is more singular, contain no channel, and but little other circumstantial proof of the action of water, by which they were certainly excavated," another thus speaks of the Green sand country between London and Portsmouth:—"In crossing this desolate region by the main road from

London to Portsmouth, it is difficult to believe that we are only forty miles distant from the capital, and midway to one of the chief naval establishments of the empire; but the nature of the soil effectually prevents improvement, and it is not impossible that this tract may remain for centuries unchanged, and still exemplify the power of geological causes in modifying the civil condition of countries, as well as their extinct features."

Uses.—The lower beds of Green sand are quarried for calcareous matter, to be used in building, and as lime. There, too, is found, in the Weald of Kent, the Kentish ragstone. A stone, nearly allied to the rag, is said to have been obtained from Boughton, near Maidstone, for the erection of Westminster Abbey. From the Green sands of Black Down Hills, Devonshire, are obtained whetstones, and many of the neighbouring inhabitants are employed in the manufacture. The chalk is used as a polishing powder or paste, for painters' whiting, &c. The flint is the most valuable mineral of the group, contributing so largely as it does to the manufacture of porcelain and glass. Gun flints, formerly an article of considerable commercial importance, are now superseded by percussion caps.

TERTIARY STRATA.

Geological Contrast between the Secondary and Tertiary Formations.—Pausing for a moment, as we now find ourselves approaching towards the close of our journey, we are struck by certain special differences between the two formations—that which we have just passed through, and that we are now about to examine. For instance, while the secondary strata retain generally an uniformity of character over immense spaces of territory, thereby suggesting the idea of an uninterrupted sequence of certain general physical agencies, the tertiary strata exhibit an almost boundless local variety, and present unmistakable relations to the existing forms of sea and land. The earth's superficial movements, during the tertiary era, seem to have been mainly confined to a general and equable rising, which had the effect of lifting above the waters all the additional part of the crust, which was considered necessary to the development of a higher and more extensive system of organic life than had previously existed. Not that Nature had ceased altogether to put forth her strength in the exhibition of the more stupendous phenomena: on the contrary, some of the grandest belong to this time. The Pyrenees were now raised. The Alps, from the Mediterranean toward Mont Blanc, reared their sublime forest of peaks. Such events would of themselves materially affect the relative levels of the sea and land.

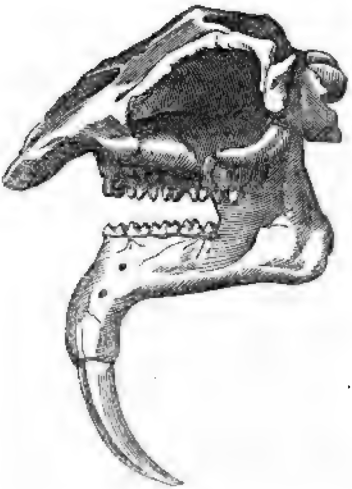
Deposition.—Although the chalk formation is the highest that extends over a very large portion of the earth's surface, there exist, in the hollows or basins formed by its beds, masses of clay, limestones, marls, sand, and gravel, loosely congregated, and of no very great thickness, but showing unequivocal marks of stratification; that is to say, of having been regularly deposited as marine or fresh-water sediments. It is this latter feature that distinguishes the strata of the group from mere superficial and accidental accumulations, such as we shall speak of in our next chapter. London and Paris both rest on basins of this kind. It is not difficult to decipher their history from an examination of their component parts. We shall take for this purpose the richer of the two basins, that of Paris, premising that such

basins are considered to be beds of gulfs and estuaries, left at the conclusion of the chalk period. Beginning from the bottom of the Paris basin, we find, first, a fresh-water deposit of clay and limestone, showing that the estuary had been stopped at the mouth by drift, or by a change of level, and thus became an inland lake. Above this stratum we find one of marine limestone, showing the sea had again broken in, and restored the estuary. Still ascending, we arrive next at a second fresh-water formation, which includes gypsum; then a second marine deposit of sandy and limy beds, surmounted finally by a third series of fresh-water strata, showing how many times that particular spot had changed its character from estuary to lake, and lake to estuary, before there was final rest. We find existing phenomena corroborative of this view. In the deltas of such rivers as the Niger, the connection of pieces of fresh water with arms of the sea is not uncommonly severed, for a time, by the accumulation of sand—or mud—banks or bars, which being again, for a time, broken through, the former state of things is restored.

Zoological Contrast between the Secondary and Tertiary Strata.—We have already pointed out one great difference between the secondary and tertiary strata—that concerning their peculiarly geological characteristics; we must now speak of another—their striking zoological distinctions. While the organic life of the former is obviously and entirely distinct from our own day, in the latter, on the contrary, it is the resemblance to the present state of things that forcibly attracts the attention. Indeed, the extent of the change between the two periods is so great, that the close of the secondary formation resembles the close of the Palæozoic period already spoken of—that is to say, there almost seems to have been an entire cessation, followed by a new creation, of life. The tertiary period is, in fact, the dawn of existing zoological science. From its commencement, and more and more as we ascend, do we find an increasing number of forms identical with those now living. The abundance of shell-fish is one of the most noticeable features; and as the quantity found varies, it is supposed, in accordance with the date of the strata in which they are imbedded, Sir C. Lyell has made use of the shell-fish to divide the whole Tertiary period into four eras—the Eocene, or dawn of recent animals, at the bottom of the group, which contains little more than 3 per cent. of surviving species; the Miocene, or less recent, which contains 18 per cent. of existing species; the Pliocene, or more recent, which yields from 35 to 50 per cent.; and the Pleistocene, the most recent, which affords from 90 to 95 per cent. of existing species. The mammalian remains of the earliest, or Eocene period, are highly important. Those of Paris alone have given forth to the light of our day some fifty species, all of which have long been extinct. The greater number belong to the order of Pachydermata, or thick-skinned animals, and to a family allied to the tapirs, which is now confined to South America and Sumatra. In another part of the Paris Eocene, the remains of the first known bi-hoofed animal, the Anoplethcrium, have been discovered. It is supposed to have been as large as an ass, but not so high, with a long tail. It is believed that its habits were aquatic, and that it was an expert swimmer and diver, though also accustomed to browse upon land. During this period fresh-water reptiles existed, serpents as large as the boa, birds of various kinds, species allied to racoons, and foxes, also bats and monkeys. In America the Eocene tertiaries make known to us the Zeuglodon, an

herbivorous feeding whale with an enormous tail, and reaching altogether to the length of a hundred feet.

In the Miocene fossils we find animals allied to the bear, horse, dog, and to the feline family, &c. Here also occurs the Dinotherium, an enormous species of tapir, exceeding in size the largest fossil elephant. Here is the portrait, as restored to us by Professor Kaup, of

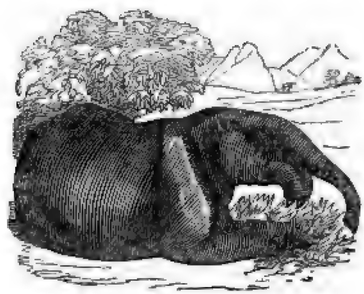


THE DINOTHERIUM.

The tusks are peculiarly the interesting feature of the Dinotherium's anatomy. Dr. Buckland has studied this subject with his usual earnestness and fulness of knowledge, and gives us, as the result, an interesting glimpse of the creature's habits. He says, "It is mechanically impossible that a lower jaw nearly four feet long, loaded with such heavy tusks at its extremity, could have been otherwise than cumbrous and inconvenient to a quadruped living on dry land. No such disadvantage would have attended this structure in a large animal destined to live in water; and the aquatic habits of the family of tapirs, to which the Dinotherium was most nearly allied, render it probable that like them it was an inhabitant of fresh-water lakes and rivers. To an animal of such habits the weight of a tusk sustained in water would have been no source of inconvenience; and if we suppose them to be employed as instruments for raking and grubbing up the roots of large aquatic vegetables from the bottom, they would, under such service, combine the mechanical powers of the pickaxe with those of the horse-harrow of modern husbandry. The weight of the head, placed above these downward tusks, would add to their efficiency for the service here supposed—as the power of the harrow is increased by loading it with weights. The tusks of the Dinotherium may also have been applied with mechanical advantage to hook on the head of the animal to the bank, with the nostrils sustained above the

water so as to breathe securely during sleep, whilst the body remained floating at perfect ease beneath the surface: the animal might thus repose, moored to the margin of the lake or river, without the slightest muscular exertion, the weight of the head and body tending thus to fix and keep the tusks fast anchored in the substance of the bank—as the weight of the body of a sleeping bird keeps the claws clasped firmly around its perch. These tusks might have been further used like those in the upper jaws of the walrus, to assist in dragging the body out of the water, and also as formidable instruments of defence. The structure of the scapula seems to show that the fore-leg was adapted to co-operate with the tusks and teeth in digging and separating large vegetables from the bottom. The great length attributed to the body would have been no way inconvenient to an animal living in the water, but attended with much mechanical disadvantage to so weighty a quadruped on land. In all these characters—the gigantic, herbivorous, aquatic quadrupeds—we recognize adaptations to the lacustrine (from *lacus*, a lake) condition of the earth, during that portion of the Tertiary periods to which the existence of these seemingly anomalous creatures appears to have been limited."

The Pliocene period is remarkable for its animals of the thick-skinned kind. This is the era of the Mastodon and Mammoth—both fossil elephants of gigantic size. One individual Mammoth was found in Siberia, in 1801, with its flesh and hide entire, preserved by the ice in which it was imbedded. Obviously, therefore, these animals, though extinct now, must have lived to a comparatively very recent period. All the principal mammalian forms appear by this time on the earth. To those already enumerated, the Pliocene adds hyenas, badgers, otters, weasels, wolves, &c. It is an interesting fact to us, as English persons, to know that in this country there were beavers of large bulk, bears, hippopotami, and the rhinoceros. In India there were, at the same time, monkeys of extraordinary size, and a tortoise eighteen feet long. The family of sloths possessed some most extraordinary representatives in the Megatherium, Mylodon, &c., which obtained their food by breaking down and devouring trees.



Uses, &c.—Passing over the igneous rocks associated with the system, of which we have already said all that is necessary in a preceding paragraph, and also over the scenery, which varies little from that of the preceding group, we may thus indicate the chief uses of the tertiary rocks. From the

upper limestone of the Paris basin are obtained the well-known Burr millstones; also a marble susceptible of high polish, and which is very ornamentally marked by the shells imbedded in it. A marl, for manure, is obtained from the disintegration of some of the limestones. Pipe and potter's clay are dug up both from the London and the Paris basins. From the latter is also obtained the famous plaster of Paris, which is gypsum, or sulphate of lime, reduced to powder and kneaded with water, for the purposes of the plasterer, the stereotype-founder, who makes his moulds of it, and the image-maker, who sends forth into our streets so many cheap and beautiful copies of the finer works of our sculptors. The gypsum itself is largely used for manure. Lignite, or wood-coal, is found in some tertiary strata—for instance, near Exeter. Amber is often found with the lignite, and is supposed to be gum that exuded from the same or neighbouring trees that formed the lignite.

CHAPTER XI.

SUPERFICIAL STRATA, &c.

Probably an era betwixt the Tertiary Formations and those of our Period.—From the depths of the earth's crust we have now re-ascended to the surface, and seem, for the moment, as we look around, to have nothing left to occupy our attention but those superficial accumulations with which our eyes and our feet have been familiar from childhood—the gravels, sands, clays, peats, &c., of our own country, and which in other countries are varied by the existence of shell-beds, coral reefs, &c. But on a more careful review we find many things of interest lying about, and the origin of which suggests interesting questions. As we examine these we are led to believe that between the era of the Tertiary strata and that to which we ourselves belong there has existed another—perhaps more than one—period, of a transitional character, to which no name has been attached, but to which belong certain clearly distinguishable phenomena.

Denudation.—We have already described the geological meaning of the word "fault." Let us now add that there are often found great faults, or hitches, in the superficial strata, which, if left as they were originally formed, must have caused striking irregularities in the face of the country, through the one side that was uplifted remaining standing up much higher than the other; but there is no such inequality left. The coal-fields of Ashby-de-la-Zouch may be instanced. Here there is a fault. We see in them that the beds, or strata, have been forcibly ruptured, and certain strata on one side raised five hundred feet higher than the corresponding and formerly united strata on the other. But if any one walks over the top of both sides he will find them level. What, then, has become of the five hundred feet of rock that must have originally projected above the surface on the raised side? It has been all washed away by the action of water. This is what is meant by *Denudation;* and we may see how potent an agent it has been in bringing the world to its present state. Professor Ramsay has shown that

certain portions of rock, removed from the top of the Mendip Hills, must have been nearly a mile in thickness, and they were also washed away by water.

There is another class of cases only to be explained by the power of denudation. We find extensive valleys hollowed out in the sedimentary strata, leaving the sides facing each other at considerable distances, and having sometimes a mass standing up between them to the same height, and evidently forming a part of the original uninterrupted range of rock before the valleys were formed by the removal of their contents. This phenomenon is explained by the action of water in washing away—and making a channel for itself through—the softer portions of the rock.

Diluvium.—This term has been applied to the next class of phenomena of which we shall speak. Below the superficial covering of mere vegetable soil, mixed as it generally is with the minute fragments of disintegrated rock, and above the stratified rocks of all eras, we find in all parts of the world, and generally in somewhat low situations, a layer of stiff clay, commonly of a blue colour, but sometimes reddish, varying in thickness from only a few feet to above a hundred feet, and mixed with fragments of rock that bear the marks of having been much rubbed and worn by travel, and which vary in size from that of an egg to the dimension of large isolated rocks, or boulders, weighing many tons. This is sometimes called the Boulder formation, and is supposed to have been the product of some vast deluge—hence the name, Diluvium—or of the sea in a state of unwonted agitation even for those agitated periods.

Boulders, &c.—The fragments in question can generally be traced to their source in certain parent masses, lying often at great distances. This is as true of the largest boulders as of the smallest stones. Thus pieces of the granite of Shap Fell are found fifty miles away from the latter; and one boulder rock, in particular, lies high up the Criffel mountain, on the opposite side of the Solway estuary. Parts of the primitive rocks of the Lammermuir and Cheviot ranges are also scattered through the vale of the Tweed, and in Northumberland. Blocks from the Welsh mountains lie about in the midland counties; and others, on the east coast, are presumed to have travelled thither from Norway. It is not likely that the exact same agency was concerned in the transport of these large masses as sufficed for the smaller ones. The latter might have been driven to and fro by the mere chaotic force of the water; the other could only have been transported to great distances by some additional power. This we find in icebergs, which, as we have already had occasion to state, are now continually transporting masses of rock. These, while imbedded in ice, are broken off from the parent mass, fall into the sea, and are then tossed about till they reach a region of a milder temperature, under which they melt and drop their inclosed burdens. In one of the recent voyages of discovery to the Arctic regions this process of transportation was seen going on. There was a dark-coloured, angular-shaped piece of rock, five or six feet wide and twelve feet high in its visible proportions, to say nothing of what might be concealed in the iceberg that inclosed it, which was between two hundred and three hundred feet high, and at least 1,400 miles from any known land. As a whole, this Boulder formation seems to tell us of a period when much of what is now dry land must have been under water—a fact that appears at once curious and interesting, if we think of it as the *latest* of an almost infinite number of

extensive risings and fallings of the earth's crust. And how this alternate action and reaction, advance and retreat, seem to foreshadow man's own mental phenomena! May we not hope that it is with him as with his material home—that on the whole he progresses grandly and beautifully, however full of reverses and disappointments his course may seem to those who look but for a time on his movements?

Marks on Rock Surfaces, &c.—In immediate connection with the phenomena we have described are certain marks or grooves often found on the surfaces of rocks in a peculiar position, and which appear to have been made by heavy and hard bodies, as they were rapidly hurried along by some irresistible force, as by that of a flood, for instance, bearing upon its bosom great masses of ice.

Crag and Tail.—The rocky elevations, abrupt on one side and gently sloping away on the other, to which geologists have applied the quaint appellation of "Crag and Tail," belong also to the peculiar class of geological effects now under review.

Clay and Gravel Ridges.—The same may be said of the long ridges of clay and gravel which are found in various parts—in Finland, Sweden, and the United States, for instance. We can readily understand how these were formed after perusing Mr. Simpson's Work on the *Polar Seas*, where he describes the breaking up, during summer, of the ice formed in the previous winter over gravelly districts, of the driving in upon the shore of the ice fragments by the wind or the tidal waves; of their accumulation on the beach in long ridges, which melting, leave the imbedded gravel behind.

The foregoing Phenomena appear to have had One Common Origin.—It is a very remarkable circumstance that all these phenomena seem to have had not only one common *general*, but also a *special* origin; that is to say, they all seem to have resulted from the action of a grand watery current sweeping from the north and north-west towards the south-east; for the directions of the diluvial blocks, of the grooved lines, of the crag and tail, and of the clay and gravel ridges, are all of that character. What sort of a current, or flood, this must have been, our readers may judge for themselves, when they know that it included within its range not only Europe, but America.

Glaciers.—The origin of glaciers is so intimately connected with that of icebergs, and also with that of the Boulder formation, that we need not apologize for the introduction of the subject in this place. By glaciers we understand those enormous masses of ice which are formed on the slopes of lofty mountains, and in the intervening valleys, and which remain apparently eternally unchangeable. Let us, with the help of an eminent foreign geologist, Saussure, picture to ourselves the aspect of the most famous of the glacial regions—that of the Alps. Let us imagine ourselves at a sufficient height above these stupendous mountains to overlook the whole, and thus be able to embrace at one view the Alps of Switzerland, Savoy, and Dauphiné. What do we then see? A mass of mountains, intersected by numerous valleys, composed of several parallel ranges, the highest in the middle, and the others gradually receding on each side. This central chain appears bristling with craggy rocks which are covered, even in summer, with snow and ice, except where their sides are directly perpendicular; while, in strange contrast, the deep valleys are green and beautiful, well watered, and covered with villages. Looking still more closely into the details of the

wonderful scene—the sublimest, perhaps, that earth can afford—we perceive that the central range consists of lofty peaks and smaller chains, snow-topped, with all the slopes that are not directly vertical covered with ice, while the intervals between form elevated valleys, containing enormous masses of ice, extending downward into the deeper and inhabited valleys of the lesser bordering chains. The chain nearest to the centre presents the same aspect on a smaller scale, but beyond that one we see no more ice or snow, except upon the peaks of some unusually high summits. Such is the home of the glacier. Between Mont Blanc and the borders of the Tyrol there are about four hundred glaciers, of which the smallest are generally two or three miles long, while most of them range from ten to fifteen miles long, and from one to two miles and a quarter broad. Altogether it has been calculated that the glaciers of the Tyrol, Switzerland, Piedmont, and Savoy cover an area of nearly fifteen hundred square miles. The constant increase of ice at the summits of the Alps, where of course the cold is greatest, would add as constantly to their height, were it not for its descent, in the form of glaciers, into and through the valleys. Sublimity is not the only element of the scene; its beauty is scarcely less attractive when we pass from the whole to study the component parts. Thus, for instance (as Sir C. Lyell notices), the ice in descending the steep slopes falling from the abrupt precipices, or in being forced through narrow gorges, is broken into a thousand fantastic or picturesque forms, with lofty peaks and pinnacles projecting upwards. "These snow-white masses are often relieved by a dark background of pines, as in the valley of Chamouni, and are not only surrounded with abundance of the wild rhododendron in full flower, but encroach still lower into the region of cultivation, and trespass on fields where the tobacco-plant is flourishing by the side of the peasant's hut."

Glacier Motion.—The cause of the motion of the glaciers has been much discussed among scientific men. The result seems to be a tolerably general agreement that the chief agent of motion is gravity, acting upon a plane more or less inclined, and upon a body capable of a certain amount of self-adaptation to the surrounding circumstances, and aided by the melting of the bottom of the glaciers, where they rest upon the earth, through the higher temperature of the latter. This self-moulding power of ice is much more considerable than one would at first suppose. The following interesting experiment was made by the secretary of the Royal Society. He filled with water a hollow shell of iron an inch and a half thick, and having an internal cavity of ten inches diameter. This was exposed to severe frost, the fuse-hole of the shell being placed uppermost. As the water froze would it burst the cell or force the ice out at the hole? The answer was the protrusion of the ice in the form of a cylinder, which grew on, inch by inch, as a larger quantity of the water became frozen. Sir C. Lyell states: "A series of beautiful experiments enabled Professor Forbes to determine, for the first time, the true laws of glacier motion, which were found to agree very closely with those governing the course of rivers, their progress being faster in the centre than at the sides, and more rapid at the surface than at the bottom. This law was verified by carefully fixing a great number of marks in the ice, arranged in a straight line, which gradually assumed a beautiful curve, the middle part pointing down the glacier, and showing a velocity there double and treble that of the lateral parts. He ascertained that the state of advance by night was nearly the same as by day, and that even the

hourly march of the icy stream could be detected, although the progress might not amount to more than six or seven inches in twelve hours." By the incessant though invariable advance of the marks placed upon the ice, "time," says Mr. Forbes, "was marked out as by a shadow on a dial, and the unequivocal evidence which I obtained that even whilst on a glacier we are, day by day, and hour by hour, imperceptibly carried on by the resistless flood of the icy stream, filled me with admiration." In order to show or explain this remarkable regularity of motion, and its obedience to laws so strictly analogous to those of fluids, the same writer proposed the theory that the ice, instead of being solid and compact, is a viscous or plastic body, capable of yielding to great pressure, and the more so in proportion as its temperature is higher, or as it approaches more nearly to the melting point.

English Glaciers.—Now, what is true of the existing glaciers of the continental Alps was doubtless also true of the glaciers of our own mountainous regions when they existed; for we have no doubt that they did exist in such districts as the Welsh mountains. The investigations of Agassiz and others, and the known greater extension of the glaciers of the Alps in past times, render it highly probable that this "ice-power," as it has been called, has been actively at work (during former eras) in parts where now no fields of ice are ever found. Applying this fact to our mountainous regions, we see at once the explanation of the smoothed and rounded rocks, the grooved surfaces, the channels parallel to the grooves, and other phenomena, for all these are known to be produced by glaciers on the surfaces they pass by or over. Of course an iceberg is but a floating glacier, and therefore there is no difficulty in understanding how the boulders we have spoken of were originally imbedded in a glacier, which was either carried by its own motion to the water, or to which the waters came in the course of the differing geological phenomena we have described. Thus, to borrow an illustration from the *Penny Cyclopædia*, the ancient glacier streams of Cumberland may have delivered the detrital blocks of Shap and Carrock into the sea by the breaking off of icebergs, which may then have been drifted by currents to Staffordshire, to the mouth of the Tyne, and the valleys of York and Holderness.

Has England had a low Northern as well as a Tropical Temperature?—All this, however, implies a considerable change in the temperature of England, which, as we have seen, was in all probability tropical during the earlier geological eras, and which, as we shall presently show, remained so during some part of the period at present under review. But such a change involves no great difficulty, when we consider that mere alterations of the relative arrangements of land and water immediately affect the temperature, and changes of that character were obviously of frequent occurrence while the earth was, as it were, making its final arrangements for the state of things which includes man. We seem, therefore, to have had a glacial period among the numerous other periods already spoken of.

Ossiferous Caverns.—But of all the results of the Diluvium phenomena the ossiferous caverns are, perhaps, at once the most popularly and scientifically interesting. These are so called from *os*, bone, and *fero*, I bear—words referring to the remarkable contents of the said caverns. They are found in various parts of the world, including our own country. The chief English ones are the following:—Banwell Cave and Hutton Hole, in the Mendip Hills; Kent's Hole, at Torquay; the Peak Cavern, in Niddesdale; and Kirkdale, in Yorkshire. They occur in the limestone strata, which are peculiarly liable to be hollowed out by the action of springs and subterranean

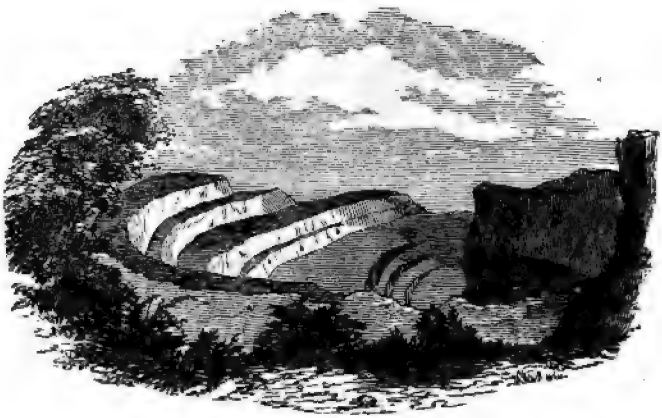
waters. We shall briefly describe Kirkdale Cave. This is situated about twenty-five miles north-east of York, and occupies an elevated position overlooking the valley of Pickering. It has been explored to the depth of about 250 feet. The breadth of the cavern varies from that of a very narrow passage to about five feet. The height generally does not exceed three or four feet, but in parts a man can stand upright. At the mouth there is an expansion, forming a kind of antechamber to this primeval wild-beast mansion; and there it was that the bones of the more important animals were found, sticking up through the floor of the stalactite caused by the droppings of the roof, like the legs of pigeons through a pie-crust, to use Dr. Buckland's savoury image. It is to this stalactite we are indebted for the preservation of the bones. Liebig's explanation of the origin of the stalactite is as follows:—He found on the surface of Franconia, where limestone caverns abound, a fertile soil, containing a considerable quantity of decaying vegetable matter, which, when acted upon by air and moisture, gives forth carbonic acid, which dissolves in rain. Rain-water thus impregnated passes through the porous limestone, dissolving some of the latter on its way, until it reaches the interior of the cavern, where it loses some of its carbonic acid by evaporation, and where it also parts with its calcareous matter, and that which remains is stalactite. Beneath the stalactite was found the true floor of clay. The bones included the remains of twenty-three species; and a most extraordinary assemblage they represented, namely—hyenas, tigers, and bears side by side with larks, pigeons, ravens, ducks, and partridges; the hippopotamus, rhinoceros, and elephant accompanied the deer (three species), the ox, and the horse; the remains of the wolf, the weasel, the fox, and the water-rat were mingled with those of the rabbit, the hare, and the mouse. The bones of the gentler animals were much broken, and presented altogether the appearance of their owners having formed the food of the fiercer ones. The remains of nearly three hundred hyenas have been traced among these bones, including individuals of every age. The species is now extinct. It was larger than the terrible hyena of South Africa, the *Hyena crocuta*. There is no doubt these animals lived here, as a large quantity of their dung was found, which, as in the case of the existing hyena, is nearly of the same composition as bone, and scarcely less durable. No doubt exists, therefore, but that these were the true tenants of the cave, and that the bones of the larger animals were brought in by them from the neighbourhood: and so we get another glimpse of England in its tropical or semi-tropical days.

Ancient raised Beaches.—In the foregoing paragraphs we have had chiefly to deal with incidents arising out of the great event or events that caused so large a portion of what had been dry land again to be buried beneath the waters. We have yet to speak of those which reveal to us the re-emerging of the land preparatory to its becoming our home. Near, and often at some distance inland from it, are found terraces of the kind shown in the following engraving, and which might almost be mistaken for the remains of some ancient amphitheatre which man had created. Such terraces are found in Britain, Scandinavia, America, &c. There can be no doubt what they are—the beaches on which the sea once rested; and their successive elevation one above another shows how the sea-bed has been itself elevated from time to time. The highest was the earliest coast line; then there was an elevation of the district, and what is now the second terrace *became* the coast line, and so on. Such risings of the sea-coast have been

going on in our own historical era. Sweden, indeed, is said to be still rising at the rate of about forty-five inches in a century.

Organic Life.—The extensive submersion of which we have spoken must have had a serious effect on the animal life of the time; but it is not true, as some have supposed, that this injury extended to absolute destruction and new creation. We find some species of the Tertiary era identical with some that now exist. A badger of the Miocene period, for instance, is considered to be indistinguishable from the badger of the present time. So, again, there exist in India many reptiles known to be coeval with the extinct Anoplotheri, Mastodon, &c., of the Himalayas.

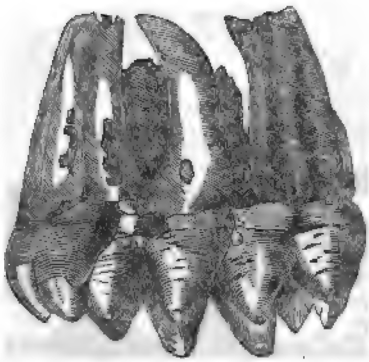
The animal remains of the other superficial strata (the latter including filled-up lakes, the deposits of rivers beside their margins, and of the greater rivers at their mouths, as in the deltas already spoken of in earlier chapters,



THE VALLEY GOZZO DEGLI MARTIRI, SICILY.

peat mosses, vegetable soils, &c.), all betoken that they belong to a zoology which was passing gradually from the Tertiary to the present period. Thus we find in superficial deposits in North America the remains of the extinct Mammoth and Mastodon by the side of the remains of the same buffalo as that which still roams in countless herds over the prairies of the same country. Again, to borrow an illustration from our own country, at Market Weighton, in Yorkshire, there have been found in the earth of a like deposit the bones of the bison, elephant, rhinoceros, wolf, some feline animal, horse, deer, and birds, all differing in some respects from their congeners of to-day, but associated with some thirteen species of shells, terrestrial and marine, which are identical with shell-fish now living in the neighbourhood. To our engraving of the Mastodon we must append a few words. It has been called the animal of the Ohio, from the number of its bones that have been found in the north part of Kentucky, near the Ohio river, at a place called (obviously in consequence) the Big-bone Lick. The engraving, in our next page, of the molar tooth of the Mastodon, which is very much reduced below the natural size, suggests, even more than the complete skeleton of the animal, its terrible size and character. It was

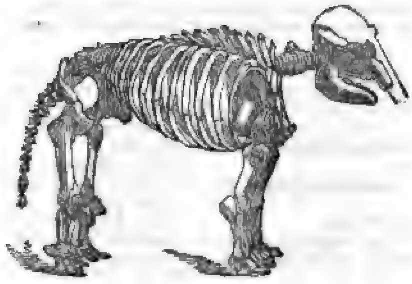
probably about the height of the elephant, but longer and stouter. M. Fabri, a French officer, told Buffon, the eminent naturalist, that the red-men of America considered these bones to belong to an animal which they named the *Père aux Bœufs*, or Father of the Oxen, and to which they attach a noticeable tradition. They say that with these animals there existed men on the same gigantic scale, and that the Great Being destroyed both wit thunderbolts. The Virginian Indians give the story to the effect that as a troop of these tremendous creatures were destroying the deer, bisons, and other animals created for their—the Indians'—use, the "Great Man" slew them all with his thunder except the Big Bull, which, nothing daunted, presented his enormous forehead to the bolts, and shook them off as they fell, till at last, being wounded in the side, he fled toward the great lakes, where he is to this day.



MOLAR TOOTH OF THE MASTODON.

The great distinction between the zoology of the present as compared wit h all earlier geological eras seems to be this:—Formerly there was an immense number of individuals in each of the species that did exist, but the number of species, and still more that of genera and orders, was limited; now, on the contrary, while there is a wonderfully rich development of various kinds of life—as shown in the great number of orders, genera, and species—the mass of individual life in each special division is proportionately limited. Development of life from a low to a higher state has been the law, not mere increase. The mode of this development is a perplexing subject. All that we can at present safely say upon it seems to be this: Looking over the whole field of creation, from its earliest to its latest manifestations, it is impossible to doubt that there has been a constant progress. We see as an obvious fact that higher and higher forms have risen as era has followed era; but whether this is to be attributed to so many special acts of creation accompanying each individual advance, or whether there was originally included in the Divine scheme of vegetable and animal life some power that should cause each form to advance a step upwards under certain stimuli, is too large and too serious a question to be discussed in our pages.

Finally, in glancing over the names of the animals whose presence in the world at this early period has been discovered by their remains, we miss certain of the most familiar forms, such as the sheep and the goat, and above all, Man himself, whom we thus perceive to be the very latest born of all the existing inhabitants of the world. In none of the older formations do we find any relics of him; nowhere, indeed, but in places and among accumulations that are evidently of the most recent character—such as in peat bogs, river sand, and the ashes and cinders of volcanic eruptions.



SKELETON OF THE MASTODON.

CHAPTER XII.

GLOSSARY OF GEOLOGICAL TERMS.

[THE object of this glossary is not merely to explain the technical terms used in the preceding pages, but also to aid the student in his perusal of geological works of a more strictly scientific character. We have not thought it necessary to repeat explanations already given, where they run to any length, or are comparatively unimportant, and have therefore in such cases simply referred to the page where the term may be found properly described. The zoological and other scientific—but not directly geological—terms that are also included, are those which commonly occur in geological treatises.]

Acephalous. A division of molluscous animals without heads, like the oyster.

Adipocire. A substance between fat and wax, formed under certain circumstances from the decomposition of animal matter buried in the earth.

Alabaster. A white semi-transparent variety of gypsum.

Albite. A variety of felspar.

Algæ. An order of the Cryptogamic class of plants, including sea-weeds, from which the name is derived.

Alluvium. Stones, gravel, earth, &c., washed away from certain parts and deposited in others, not constantly covered with water.

Alum-stone. Alum is the basis of pure clay. For *Alum*, see p. 245.

Ammonite. Extinct molluscous animals allied to the Nautilus, and living in a chambered shell curved like a snake's coil.

Amorphous. Bodies without regular form.

Amygdaloid. One of the trap rocks, containing agates and *almond*-shaped minerals.

Analcine, or *Cubizite.* A mineral often found in the trap rocks.

Analogue. A body (of one period) corresponding with another (of a different period).

Ancient Raised Beaches. See p. 260.

Anthracite. A kind of mineral charcoal, shining, and somewhat like blacklead. See p. 229.

Anticlinal, or *Saddle-back Strata.* Bending from a common centre towards opposite sides.

AQUEOUS ROCKS. See p. 194.

Arenaceous. Sandy.

Argillaceous. Clayey.

Arragonite. A mineral first found in Arragon, in Spain, and composed of carbonate of lime.

Augite. A dark green or black mineral, forming one of the constituents of certain volcanic rocks.

Artesian Wells. These are made by boring perpendicularly through various strata, and generally to a great depth. First practised at Artois, in France: hence the name.

Atolls. Ring-shaped coral islands.

Avalanches. Masses of snow formed at great heights in the Alps, and which, as they break away and descend, become frequently of enormous size through fresh accumulations.

Basalt. One of the most common and interesting varieties of the trap rocks. See p. 237.

Basin. Deposits lying in a cavity or depression in the earlier rocks, such as the Paris Basin and the London Basin.

Belemnites. Extinct molluscous animals, having a chambered shell, straight, long, and conical.

Bitumen. Mineral pitch. See p. 200.

Bituminous Shale. A clayey mud strongly impregnated with bituminous matter.

Blende. A metallic ore, found in brown and shining crystals, and consisting of a compound of zinc and sulphur.

Bluffs. High precipitous banks overhanging seas, &c.

Botryoidal. Resembling in form bunches of grapes.

Boulders. Great blocks of stone, found scattered about in places to which they do not naturally belong, and which, therefore, have been transported from other parts, which are often traceable, and lying at a great distance. See p. 256.

Breccia. Angular rock fragments connected by some mineral substance, such as lime.

Calc Sinter. Petrifying springs. A German term.

Calcaire Grossier. Certain strata of the Paris Basin.

Calcareous. Containing lime.

Calcareous Rock. Limestone.

Calcareous Spar. Crystallized carbonate of lime.

Calcedony. An uncrystallized flinty mineral.

Carbon. One of the elementary bodies, which can neither be decomposed nor burned.

Carbonate of Lime. Lime in combination with carbonic acid.

Carbonated Springs. Natural springs highly charged with carbonic acid gas, and of frequent occurrence in volcanic districts.

Carbonic Acid Gas. The gas obtained artificially by the slow burning of charcoal, and which often issues naturally from the earth, especially in volcanic countries.

Carboniferous. A group of the secondary strata, otherwise known as the coal formation. The word is also applied to any stratum containing coal.

Cataclysm. A deluge.

Cephalopoda. Molluscous animals with the organs of motion around their heads.

Cetacea. The whale family. An order of animals, vertebrated and mammiferous.

Chalk. White earthy limestone. For *Chalk System*, see p. 247.

Chert. A flinty mineral, approximating to flint and calcedony.

Chloritic Sand. Sand of a green colour, which it derives from the presence of the mineral chlorite.

Clay Slate Formation. See p. 216.

Clay and Gravel Ridges. See p. 257.

Cleavage. The quality possessed by slate rock of being cloven into thin laminæ, or plates. See p. 217.

Clinkstone, or *Phonolite.* So called from the sonorous sound it emits when struck. One of the trap rocks.

Coal Formation. See *Carboniferous;* see also p. 229.

Coleoptera. Beetles with four wings, the upper pair hardened into a shield.

Conformable. Strata lying one above the other, in the same direction, are conformable; but when they lie in different directions, as when one is inclined and the other horizontal, they are called *unconformable*.

Congeners. Species belonging to the same genus.

Conglomerate, also called *Pudding-stone*, consists of pebbles of rock-fragments set, as it were, in a cement or paste formed by another mineral substance.

Coniferæ. Plants like the pine and fir, which have their seed in cones.

Coprolites. Petrified animal excrements.

Cornbrash. A rock that *breaks* readily under the action of the plough in the preparation of the soil for corn.

Corals. See p. 210.

Cosmogony, or *Cosmology.* Words expressive of speculations regarding the origin of the earth. See p. 187.

Crag. Certain Tertiary deposits of sand with shells, &c., are so called in Norfolk and Suffolk.

Crag and Tail. See p. 257.

Crater. The circular cavity or chimney through which volcanic matter is ejected.

Cretaceous. Chalky.

Cretaceous System. One of the systems of the Secondary strata. See p. 247.

Crop out. When strata are pushed up above the surface of the earth, they are said by miners to *crop out*.

Crust of the Earth. See p. 190.

Crustacea. Animals of the crab and lobster class, which possess a hard shell or crust, which they renew periodically.

Cryptogamic Plants are such as mosses, ferns, and sea-weeds, in which the organs of reproduction are concealed.

Crystals. The regular forms with facets like those of the cut glass of our chandeliers, in which simple minerals are often found, are known by this name. Such minerals are said to be crystallized. When regular crystals are broken, or when a mineral consists of a confused mass of ill-defined crystals, they are said to be crystalline. Loaf-sugar is crystalline; sugar-candy crystallized.

Cupriferous. Copper-bearing.

Curved or *Contorted Strata.* See p. 196.

Cycadeæ. Tropical plants with a short stem, and leaves that branch out in a circular form, and are called *pinnated fronds*.

Cyperaceæ. Plants like the English sedges.

Debacle. A great rush of water, carrying before it and spreading on its way fragments of the rocks that had previously *barred* its way.

Débris. Loose materials arising from the disintegration of rocks.

Degradation. The slow wearing down of a part comparatively high to a lower level. Thus hills are degraded by rains and rivers.

Delta. The land formed at the mouths of great rivers by the transport and deposit of sediment contained in the latter.

Denudation. Parts of the surface of the earth laid bare by the action of running water. See p. 255.

Deposit. Matter settled down from water.

Detritus. The particles or fragments rubbed off from rocks.

Diluvium. The loose materials collected together by the action of a deluge or some powerful current of water. See p. 256.

Dip. Inclined strata are said to *dip* towards some point of the compass; and the angle they make with the horizon is the angle of inclination or dip.

Diptera. The order of insects that possess but two wings.

Disintegrate. To break asunder solid substances. Rocks are disintegrated by frosts, &c.

Dislocation. Put out of place.

Disrupting. Breaking asunder.

Dolerite. A trap rock, composed of felspar and augite.

Dolomite. A crystalline limestone containing magnesia.

Dunes. Low hillocks of sand blown together by the wind on the sea-shore.

Dycotyledonous. Plants having two seed-vessels, or lobes, and which form one of the grand scientific divisions of the vegetable world.

Dykes. Igneous rocks injected through a rent in the superincumbent strata. See p. 195.

Embouchure. The mouth of a river, or the area over which it extends in entering a sea or lake.

Encrinites. See p. 225.

Eocene. Sir C. Lyell's name for the lowest portion of the Tertiary strata.

Escarpment. The precipitous front of a high ridge of land.

Estuaries. Openings of the land from the sea, through which both rivers and tides find way.

Exuviæ. In geology, this means the fossil shells and other animal remains found in the earth's crust.

Faluns. A French name for Tertiary strata with shells, resembling the Norfolk crag.

False Strata, or *Interstratification.* See p. 195.

Fault. A break or dislocation of strata, leaving a crack between (generally filled up with rubbish), and with the strata on one side higher than the corresponding parts on the other. See p. 195.

Fauna. The animals natural to a country constitute its *Fauna*, as the plants form its *Flora*.

Felspar. The white angular grains of granite. This simple mineral (see *Simple Minerals*), next to quartz, is the chief material of rocks.

Ferruginous. Containing iron.

Fissile. Easily cleft.

Flint. See p. 247.

Floetz Rocks. A German term for the Secondary strata, which was supposed to occur chiefly in *flat* beds.

Flora. See *Fauna.*

Fluviatile. Belonging to a river.

Formation. A group of strata referred to one common period or origin.

Fossils. The petrified remains of animals and plants. See p. 197.

Fossils, lowest strata containing. See p. 217.

Fossiliferous. Containing fossils.

Fractures. See p. 194.

Freshets. Land-floods through the sudden rising of rivers.

Galena. A metallic ore consisting of lead and sulphur.

Ganoids. An order of fishes covered with angular and *regularly* arranged scales, composed internally of bone, and coated with a most brilliant enamel.

Garnet. A crystallized mineral, or precious stone, generally of a deep red colour, found in the igneous rocks.

Gasteropods. Testaceous animals with a foot directly attached to the body, as in the limpet.

Gault, or *Galt.* Beds of clay and marl lying between the Upper and Lower greensand. See p. 247.

Geodes. Rounded stones, and which sometimes have a cavity within lined with crystals. Also, hollow nodules of ironstone.

Geology. The science relating to the origin, formation, and structure of the earth. See p. 187.

Glacier. Hardened masses of snow of immense size, found in Alpine regions. See p. 257.

Glacis. An easy slope.

Gneiss. One of the stratified primary rocks. See p. 214.

Gramineæ. Plants of the grass order.

Granite. An igneous rock, probably the earliest in formation of all rocks, and the one from which, by decomposition and other causes of change, most, if not all later rocks have been formed. See p. 213.

Grauwacke. Grey rock. One of the Primary or Transition strata. See p. 216.

Greensand. Strata of sand, sandstone, and limestone belonging to the Cretaceous, or chalky group. See p. 247.

Greenstone. A trap rock consisting of felspar and hornblende.

Greywacké, or *Grauwacke.* Some of the oldest fossil-bearing strata are thus called from their grey colour. The name comes from the German miners.

Grit. Coarse-grained hard sandstone.

Gymnospermous. Plants with naked seeds forming one of the five great botanical divisions.

Gypsum, or sulphate of lime. A mineral compound of lime and sulphuric acid.

Gyrogonites. Seed-vessels of fresh-water plants of the genus Chara.

Heterocercal. A word applied to those fishes which have, like the shark, the tail divided into two unequal parts. This is a distinguishing feature of the early fossil fishes—all, indeed, below the magnesian limestone.

Horizontal Strata. See p. 195.

Hornblende. A simple mineral entering largely into the composition of several of the trap rocks, and which is of a dark green or black colour.

Hornstone. A mineral substance nearly resembling flint.

Hydrophites. Aquatic plants.

Hypogene Rocks. Rocks formed under—and not on—the surface. The igneous belong to the first class, the sedimentary to the second.

Icebergs. Great floating masses of ice, found in the polar and adjoining seas.

Ichnites. Fossil footsteps. See pp. 235, 241.

Ichtyolite. A fish, or any portion of a fish in a fossil state.

Ichthyosaurus. A gigantic fossil lizard, partly allied to fish, inhabiting the seas in early geological periods.

IGNEOUS ROCKS are such as granite, trap, and lava, which are supposed to have been formed by the action of heat, which reduced their constituents to a fluid or viscous substance. See p. 193.

Incandescent. White-hot.

Inclined Strata. See p. 195.

Infusory Animalcules. Microscopic creatures living in liquids, or *infusions* of various kinds.

Inspissated. Thickened.

Invertebrated Animals are such as have no back-bone.

Isothermal Lines are lines of equal heat, drawn in zones or divisions round the globe. Thus, if we begin at any one place with a certain degree of mean annual heat, we pass on, not necessarily in direct lines, but through those places that we know by experience present the same mean annual temperature.

Joints. The partings in rocks, such as those which divide basaltic columns into prisms, &c.

Jura Limestone. The mountains of Jura, between France and Switzerland, are chiefly composed of oolitic limestones: hence the name given to the group.

Keuper. The German name for a stratum of the Upper New Sandstone.

Kimmeridge Clay. A thick bed of clay, found at Kimmeridge, in the isle of Purbeck, Dorsetshire, and belonging to the Oolitic group.

Lacustrine. Belonging to a lake.

Lagoons. Creeks and pools of water on the sea-coast.

Lamelliferous. Having a structure like that of thin leaves or plates.

Laminæ. Plates. In geology this expresses the thin layer of which an individual stratum is often composed.

Landslip. Land disturbed by an earthquake, or by the undermining of its base by water, and which, consequently, slips or falls down from its place.

Lapidification. The conversion into stone.

Lapili. Small cinders from volcanoes.

Lava. The stone thrown in a fluid state by volcanoes.

Lepidodendron. Fossil plants of the coal measures, occupying a position between coniferous plants and lycopodiums.

Leucite. A white, simple, crystallized mineral, found in volcanic rocks.

Lias. The provincial name for a clayey limestone, and adopted by geologists for the group of the Secondary strata, in which it is found. See p. 244.

Lignite. Wood converted into a sort of coal.

LIFE ON THE GLOBE, First appearance of, see p. 217. First appearance of land animals, see p. 235.

Lithodomi. Animals belonging to the mollusca, which lodge in holes in rocks, that they form by means of some chemical solvent.

Lithogenous Polypes. Coral-forming animals.

Lithographic Stone. A limestone of slaty and compact texture, yellowish colour, and fine grain.

Lithoidal. Possessing a stony structure.

Lithological. A word that is used to express the stony character of any mineral mass.

Lithophagi. Another class of molluscous animals, that eat out holes in the solid rock for their residence.

Lithophites. The animals that make the stone-coral.

Littoral. Belonging to the shore.

Loam. Sand and clay mixed.

Lophiodon. Extinct fossil quadrupeds allied to the tapir.

Lycopodiums. In English they are called *Club Mosses.* The fossil species grew to a vast size, rivaling that of modern pine-trees.

Lydian Stone. A flinty slate, allied to hornstone, of a greyish-black colour.

Macigno. An Italian term for a flinty sandstone.

Madrepore. Corals mostly distinguished by their star-shaped cavities.

Magnesian Limestone. A group of strata lying above the coal measures, and containing much magnesia.

Mammifers. Animals that suckle their young.

Mammillary. The breast or pap.

Mammoth. An extinct species of the elephant.

Marl. Clay and lime mingled. When hard it is called indurated marl.

Marks on Rock Surfaces. See p. 257.

Marsupial Animals. Quadrupeds having a bag under their belly, in which they carry their young.

Mastodon. Extinct animals, allied to the elephant.

Matrix. When a shell or simple mineral remains undetached from its native place it is said to be in its matrix.

Mechanical Origin, Rocks of. These are to be distinguished from rocks of chemical origin. Sand, pebbles, &c., belong to the former. All those which possess a crystalline texture belong to the latter kind.

Medusæ. Shell-less, marine animals, whose organs of motion spread out or radiate like the snaky hair of the mythological Medusa.

Megalosaurus. A gigantic fossil animal resembling the lizard.

Megatherium. An extinct fossil animal of gigantic size, resembling the sloth.

Metallization. See p. 200.

Mesotype. A white, needle-shaped, simple mineral, found in the trap rocks.

Metamorphic Rocks. These are rocks presumed to be formed by sedimentary deposits, arising from the decomposition of the igneous or primary rocks, and altered by igneous action.

Mica. A bright, silvery-looking, simple mineral, which may be split into thin, elastic scales. It is these scales which look so brilliant in granite.

Mica Schist, or *Mica Slate.* One of the metamorphic rocks. See p. 215.

Miocene. One of Sir C. Lyell's divisions of the Tertiary strata.

Molasse. A soft, green sandstone, largely developed in Switzerland, in connection with the Miocene Tertiary period.

Mollusca. Soft-bodied, boneless animals, such as shell-fish.

Monad. The minutest of the visible animalculæ, supposed by some naturalists to be the elementary molecules of organic beings.

Monitor. An animal of the lizard tribe.

Monocotyledonous. Referring to plants having only a single seed-lobe, or cotyledon. On this characteristic is founded one of the great divisions of the vegetable world.

Moraine. The *débris*, or broken-down fragments, brought into valleys by glaciers.

Mountain Limestone, or *Carboniferous Limestone.* This forms a series of strata lying at the base, and forming a part of the coal measures. See p. 225.

Moya. Mud poured out from volcanoes.

Multilocula. Many-chambered. Referring to shells, like the ammonite, &c.

Muriate of Soda. Common salt, which is composed of muriatic acid and soda.

Musaceæ. Tropical plants allied to the plantain.

Muschelkalk, meaning shell limestone. This belongs to the Upper New Red Sandstone group, and is largely developed in Germany, whence comes the name.

Naphtha. A thin volatile fluid and inflammable mineral, which rises from the earth in springs, and chiefly in volcanic districts.

New Red Sandstone. One of the groups of the Secondary strata. See p. 239.

Nodule. An irregularly shaped, but generally somewhat roundish lump.

Nucleus or *Kernel.* In geology, a solid centre, round which other matter has collected.

Nummulites. Extinct molluscous animals, of a thin, lenticular shape, commonly divided into small chambers.

Obsidian. A kind of lava, like green bottle-glass, almost black in large masses, but semi-transparent in thin pieces. Pummice-stone is a peculiar form of obsidian, and produced, it is supposed, by the expansion of steam, when water had access to the heated and melted stone.

Ochre. An earth mixed with oxide of iron, forming together a yellow, powdery substance.

Ogygian Deluge. A traditional deluge, which is supposed to have happened in the year 1764 B.C., in the reign of Ogyges, in Attica.

Old Red Sandstone or *Devonian.* A group of strata largely developed in Devonshire, and which occurs immediately below the Carboniferous group. See p. 221.

Oligoclase. A felspar mineral.

Olivine. A simple mineral, semi-transparent, and olive-coloured, occurring in grains and crystals in the trap rocks.

Oolite. A limestone composed of particles shaped like the egg or roe of fish, and which gives name to one of the groups of the Secondary strata. See p. 243.
Opalized Wood. Wood which has acquired, by petrifaction, a structure similar to that of the simple mineral, opal.
Ophidious Reptiles. Vertebrated animals, such as the serpent.
Organic Remains. The petrified or fossil remains of plants or vegetables.
Origin of the World. See p. 187.
Orthocerata. Extinct molluscous animals, living in a long-chambered, conical shell, like a straight horn.
Oryctology. Reasoning or discussing upon things dug up—another and inferior term for fossil remains.
Osseous Breccia. Fragments of stone found cemented together in caverns, &c.
Ossiferous Caverns. See p. 259.
Osteology. The part of anatomy that treats of the bones.
Out-liers. Portions of a stratum lying at some distance from the parent mass.
Ovate. Egg-shaped.
Ovipositing. Egg-laying.
Overlying Strata. See p. 195.
Oxide. Oxygen in combination with some metal, the name of which is, of course, usually added.
Oxygen. A constituent part of the atmosphere, and the one that is essentially the vital part.
Pachydermata. Quadrupeds with thick skins, such as the elephant, horse, &c.
Palæontology. The science relating to fossil remains.
Palæotherium. An extinct fossil quadruped resembling a gigantic pig.
Pelagian. Relating to the deep sea.
Peperino. A volcanic rock, formed by the cementing together of cinders, sand, or scoriæ.
Peroxide of Iron. When oxide of iron, or rust, has absorbed as much oxygen as it is capable of, the product is peroxide of iron.
Petrifaction. The changing into stone. See p. 199.
Petroleum. A liquid mineral pitch, which oozes, like oil, from out of the rocks where it is found.
Phlegræan Fields, or *The Burnt Fields.* The name given by the Greeks to the country round Naples, on account of the igneous action everywhere traceable.
Pisolite. A stone, which looks in structure like an agglutination of peas.
Pit Coal. The common coal we burn, which is obtained by digging in pits.
Pitchstone. A rock with an unctuous appearance and uniform texture, belonging to the igneous rocks.
Placoids. An order of fishes, covered irregularly with plates of enamel. It comprehends all the cartilaginous fishes, such as the shark, with the exception of the sturgeon.
Plastic Clay. The clay used for pottery, and which forms one of the beds of the Eocene Tertiary period. The name is applied to a group of sands and clay.
Plesiosaurus. An extinct fossil animal of amphibious habits, resembling the crocodile.
Pliocene. Older and Newer. Sir C. Lyell's names for those two divisions of the Tertiary period which are the most modern.
Plutonic Action. The action of volcanic heat and other subterranean agencies under pressure.
Plutonic Rocks. Granite, porphyry, and the other igneous rocks, which are supposed to have been solidified from a melted state.
Polyparia. A class of the coral family.
Porphyry. One of the igneous or Plutonic rocks.
Portland Beds—Portland Limestone. Limestone strata, of the Oolitic group, found chiefly in the isle of Portland, on the Dorset coast.
Pozzuolana. Volcanic ashes, similar in nature to Roman cement, and used in Italy for mortar.
PRIMARY ROCKS. See p. 212.
Producta. Extinct fossil, two-valved shells, found in the older Secondary rocks.
Pterodactyl. A flying reptile, found in the oolite and muschelkalk.
Pudding-stone. Same as conglomerate.
Pulverize. To reduce to powder.
Pumice. See *Obsidian.*
Purbeck Limestone and *Purbeck Beds.* Limestone strata of the Wealden group.
Pyrites, Iron. A compound of sulphur and iron, occurring in rocks of almost all kinds and periods. Its appearance is that of yellow shining crystals like brass.
Pyrometer. An instrument for the measurement of heat.
Quadrumana. Four-handed. The order of animals to which apes belong.
Qua-qua-versal Dip. The inclination or dip of beds from a centre to all parts of the compass.
Quartz. A simple mineral, consisting of pure silex.
Rain-drops of remote eras. See p. 242.

Red Marl. A name for the New Red Sandstone.
Rock, and *Rock Classification.* See p. 193.
Rock Salt. Common salt, found in vast beds in different formations, as in the New Red Sandstone of Cheshire.
Rubble. The fragments of stone, broken off or worn away from a mass, are called thus by the quarry men.
Ruminantia. Animals such as the ox and deer, which chew the cud.
Saccharoid. Stone with a texture resembling that of loaf-sugar.
Salt. See p. 240.
Salt Springs. Springs of water impregnated with common salt.
Sandstone. Any stone composed of grains of sand, whether the latter be of limy, flinty, or other mineral character.
Saurians. Animals of the lizard tribe.
Saxicavous. Hollowing out stone.
Schist. Generally meaning slate. But there is a difference between a schistose and slaty structure. Gneiss, mica schist, and other of the primary rocks, cannot be split into an indefinite number of parallel plates, or leaves, like true slates.
Scoriæ. Volcanic cinders.
Seams. Thin layers separating strata of greater magnitude.
SECONDARY STRATA. See p. 221.
Secretion. Animals and vegetables are able to secrete, that is, separate, or draw out from the substances that nourish them, peculiar products. Bile is a human secretion; coral, a secretion of certain animalculæ; gum, a vegetable secretion.
Secular Refrigeration. The periodical cooling and consolidation of the globe.
Sedimentary Rocks. Those formed from the deposit of their materials, as sediments from water.
Selenite. Gypsum, or sulphate of lime, a simple crystallized mineral.
Septaria. Stone balls of a flat shape, consisting generally of ironstone, which, when broken, are found to be separated in the interior into irregular masses.
Serpentine. A rock presenting the aspect of a serpent's skin, and usually containing much magnesia.
Shale. Hardened slaty clay.
Shell Marl. Clay, peat, and other substances mixed with shells, deposited at the bottom of lakes.
Shingle. The loose, water-worn gravel and stones on the sea-shore.
Silex, or *Silica.* One of the pure earths. Flint is wholly composed of this.
Silicate. A chemical compound of silica with some other substance, such as iron, making silicate of iron.
Silt. Finely comminuted (or divided) sand, clay, and earth, transported by running waters.
Silurian Formation. A group of calcareous and clayey beds, occurring between the Grauwacke and Old Red Sandstone. See p. 216.
Simple Minerals. These words, which occur frequently in our glossary, are used to distinguish individual mineral bodies from rocks, which are composed usually of an aggregate of the same bodies. They are not simple, that is to say, uncompounded, in the chemical sense, for they can be analyzed into various substances.
Sinter. A rock dropped or precipitated from mineral waters.
Slate. See *Schist*, also *Cleavage.*
Slip. A lesser "fault." See p. 195.
Solfaterra. A volcanic rent, emitting various gases and vapours, sulphurous acid, &c.
Sporules. The seed or reproductory corpuscules (minute bodies) of cryptogamic plants.
Stalactite and *Stalagmite.* Stalactites are long rods of stone, like icicles, hanging from a roof, and are produced by the deposit of the lime contained in the dropping water. Stalagmite is the crust formed on the floor by the dropping of the same kind of water, the lime being there deposited, and the water passing away by evaporation.
Steppes. Vast plains in Northern Asia, analogous to the prairies of North America and the pampas of South America.
Stilbite. A simple mineral, crystallized, usually white, and found in the trap rocks.
Strata, Stratified, Stratification. A stratum means matter *strewed* out by the motion of water or of wind. Geology shows us that a vast number of individual strata have been thus formed one above another at very different periods, and under very different circumstances: from the study of these results all we know of the science. See p. 191.
STRATA, BRITISH, TABULAR VIEW OF, p. 201.
Strike. The line of bearing, or direction of strata, which is at right angles to their prevailing dip.
Stufas. Jets of steam, often above the boiling point, issuing from clefts in the ground of volcanic districts.
Sub-Apennines. Low hills lying at the

base of the hills usually known as the Apennines. The word is also used in connection with a series of strata of the Older Miocene period.

Sub-Crystalline. Imperfectly crystallized.

Sulphur, or *Brimstone.* A yellow mineral, found chiefly in volcanic districts.

Syenite. A sort of granite, brought from Syene, in Egypt.

Synclinal. Bending or inclining towards a common centre, as the sides of a basin towards the bottom.

Talus. Pieces of rock broken off from the steep face of the parent mass, and heaped together at the foot in a sloping form.

Tarsi. Insects' feet, articulated, and formed of not more than five joints.

TERTIARY STRATA. See p. 251.

Testacea. Molluscous animals, such as oysters, &c., having a shell.

Thermal. Hot.

Thermo-Electricity. Electricity developed by heat.

Thin-Out. If a stratum grows thinner in any direction, so that at last the two surfaces meet, and disappear in each other, it is said to thin-out.

Trachyte. One of the trap rocks. It is a variety of lava, consisting chiefly of glassy felspar, and sometimes containing hornblende and augite. In structure it is like porphyry, through the presence of detached crystals of felspar.

Theroid Animals. From *therion*, wild beast. Applied with a prefix to extinct fossil animals, whose habits are not yet satisfactorily discovered, as the *Megatherium*, *great* wild beast, and so on.

Trap Rocks. These are of volcanic origin, and consist mainly of felspar, augite, and hornblende, which, mingling in various forms and proportions, give basalt, greenstone, amygdaloid, dolerite, &c. See p. 224.

Travertin. A white, hard, concretionary, and semi-crystalline limestone, deposited from springs.

Tripoli. A powder, composed of the flinty coverings of Infusoria, imported from Tripoli, and used for polishing stones and metals.

Tropical Climate in England. See p. 233.

Tufa, Calcareous. A rock of a porous nature, deposited from water containing lime on its exposure to the air. Remains of plants and other organic substances incrusted with lime are usually found in tufa.

Turbinated. Spiral, or screw-shaped shells.

Tufa, Volcanic. A volcanic, earthy rock, composed of a mingling of fragments of scoriæ and other loose materials.

Turrilite. Extinct chambered shells, allied to the Ammonites.

Unconformable Strata. See p. 197, and also *Conformable*.

Unoxidized, Unoxidated. Not combined with oxygen.

Valleys of erosion are formed by the denuding power of water; flat valleys, by the silting or earthing up of chains of lakes; valleys of depression, by subterranean sinkings; and there are also valleys formed by the rents and cracks resulting from earthquakes.

Veins, Mineral. Fissures in rocks filled up by substances different from the rocks themselves. See p. 195.

Vertebrated Animals. Those having a back-bone, as men, and all the higher animals. One of the great zoological divisions is founded upon this characteristic.

Vertical Strata. See p. 196.

Vesicle. A little cell or bladder.

Vitrification. Conversion by heat into glass.

Volcano. The thing needs no description here. The word comes from *Vulcan*, the Fire-god of mythology.

Volcanic Bombs. Masses of melted lava ejected from volcanoes, and which, as they fall, take a pear or bomb shape.

Volcanic Foci. The subterranean points or centres of volcanoes, where the forces are supposed to exist in the greatest intensity.

Wacke. A soft and earthy variety of basalt.

Warp. The deposit from muddy waters, directed by artificial means upon low lands.

Wealden Clay. A group of strata belonging to the Oolitic system. See p. 244.

Zechstein. Mine-stone. Containing copper ore.

Zeolite. A family of simple minerals, usually found in the trap rocks. This includes Analcine, Mesotype, Stilbite, &c. When exposed to the blowpipe they boil up, as it were; hence the name (from the Greek, *to boil*, and *stone*).

Zoophytes. These include corals, sponges, and other allied aquatic animals. They are called Zoophytes, or animal plants, because they possess some of the characteristics of the life of the first, with the forms and fixed homes in the ground of the second.

In bringing our geological treatise to a close, we would observe that the latest series of geologic changes has been the rise of the land out of that deep immersion in the sea which the superficial formation evidences. We have clear proof that this emergence was not sudden and complete, but slow, and by a series of movements. This proof lies in the existence of *ancient beaches* at various elevations above the present shore. We generally detect such an object by its levelness along some considerable tract, and by the indentation of rocks, or the deposit of sands and gravels, mingled as these occasionally are with deposits of shells. All our valleys exhibit such terraces more or less conspicuously, proving that they were at one time the beds of estuaries.

Of man himself no remains have been found, save in the most recent and superficial deposits—as alluvial mud, calcareous breccia, volcanic tufa, and the like—thus proving him to be one of the latest, if not the very latest, inhabitant of this globe.

The history of the earth thus presents a long series of mineral and vital gradations, as yet but imperfectly interpreted by geology. The stratified formations, from the gneiss to the existing surface, bear evidence of these gradations, both in their composition and modes of aggregation; so also do the unstratified rocks—the granitic, trappean, and volcanic compounds—by the order in which they succeed each other. We see in these successive formations the fragments, as it were, of a history of organic being. We look in upon it, it may be said, from time to time, find that many changes have taken place in the intervals, yet always see a connection between the present and past, assuring us that the whole is essentially connected. We see, too, that a steady progress has been maintained all through, from invertebrate to vertebrate forms, from the fish to the reptile, and from the reptile to the warm-blooded animal; man finally coming upon the scene as a crowning work. It is a most interesting and elevating study, never failing, we believe, in well-ordered minds, to exalt our conception of the Divine power and excellence.

[END OF GEOLOGY.]

PART III.

ZOOLOGY.

ZOOLOGY.

INTRODUCTORY CHAPTER.

> "Look on the frame
> Of this wide universe, and therein read
> The endless kind of creatures, which by name
> Thou canst not count."—SPENSER.

ZOOLOGY is derived from two Greek words, and means a knowledge of animals. It teaches their structure, habits, and classification: the person by whom such knowledge has been acquired is a *zoologist*.

To what kind of creatures the term "animal" is applicable has now to be considered. A party of children, when discussing it in my hearing, settled, in the first instance, that cows, dogs, horses, and all four-footed beasts were animals; then that geese, turkeys, and birds of all kinds were likewise animals. To this there was one dissenting voice—one little fellow stoutly maintaining that the large birds were animals, but that the little birds were not. He was rebuked, however; and the party next proceeded to enrol fishes in their list of animals, which was unanimously agreed to. A difference of opinion existed as to whether frogs and snakes should be included; but this was finally done. I ventured to ask if a snail, a spider, and a star-fish might not also be honoured with a place in the list of animals; but the judges, one and all, pronounced the decision of the court, as if by one impulse, and all speaking at the same time—"No, no; such creatures are not animals at all."

The naturalist does not, however, use the term "animal" in so restricted a sense; he includes in it all organized existences which do not belong to the vegetable tribes; and, beginning with those which are so minute as to be unseen, save by the assistance of the microscope, rises through the various tribes of animals, until he attains to man himself.

It is worthy of remark, however, that the beings which the children agreed to place together do, in reality, constitute the group to which the highest rank is assigned. They are distinguished by one very obvious characteristic—they have a skull and back-bone. The back-bone, as every one knows, is composed of joints, or *vertebræ*; hence all animals possessing these are called *vertebrate*; and, of course, those in which the skull and back-bone are wanting are called *invertebrate*.

According to Agassiz,* the number of vertebrate animals may be estimated at 20,000; and the entire number of species of all the animals now living at 250,000. At first sight it seems a hopeless task for man to attain to any

* Agassiz and Gould, "Principles of Zoology."

knowledge of such a multitude, and this feeling is increased if we turn our attention to species now extinct, but whose remains are known to us in a fossil state. Supposing that the entire number of fossil species only equalled those which are now living, we have altogether, at what Agassiz considers a very moderate computation, half a million of species.

But though one man could of himself do little, the combined exertions of many labourers, working at the same time in various countries, may do much. And as each generation transmits, by means of books, the knowledge it has acquired, each successive generation starts on its researches from the vantage ground gained by the labours of its predecessors.

It is obvious, however, that in order that men may be enabled to preserve and disseminate their knowledge, the entire animal kingdom must be divided into provinces, well defined and properly named; and as each province in a country is subdivided into counties, baronies, parishes, and townlands, so each in the animal kingdom is parcelled out into smaller divisions according to established rules, and known by distinctive appellations.

How is this to be accomplished? If we turn to the vertebrate animals, we might say that beasts walk on the ground, birds fly in the air, fishes swim in the sea; and this would be quite true, and in a popular and general sense quite correct. But it is not sufficiently precise and definite for the zoologist. He asks, Is the bat to be classed as a bird, because it flies in the air? Is the whale to be regarded as a fish, because it swims in the sea?

Questions such as these may be discussed with great advantage, and with manifest pleasure, by a class of learners who are under the management of a judicious and well-informed teacher. By queries addressed to each in succession, he engages them all in the inquiry; elicits whatever information they possess; makes each feel as if he himself was engaged in solving a problem of considerable interest; and when he has led them to the very boundaries of their knowledge, should they be still unable to expound the point in question, they are alive to its importance, and prepared to receive such information as he may think fit to impart. His words then fall like seed upon good soil, and bear fruit abundantly.

I well remember the lively interest excited in a class of intelligent girls by the discussion of the question, if a bat, because it could fly in the air, should be considered a bird? The answers went to show that there were important points of difference between them. The bird was covered with feathers—the bat with fur; the bird had a horny beak—the bat, a mouth with teeth of a peculiar form; and finally, the young bird was hatched from an egg—the young bat, on the contrary, was born alive, and suckled by the parent.

On one occasion the question, if the whale was a fish, was discussed at greater length by counsel learned in the law, and before a judge and jury. In New York, many years ago, a dealer in oil refused permission to a government inspector of fish oil to examine his stock, alleging that he had no oil in his store but whale oil; and as the whale was not a fish, the officer had no business with it, nor was it liable to any duty as fish oil. The government, however, did not admit the plea, and the point came before a legal tribunal for decision. On behalf of the government it was argued that the whale was always spoken of as a fish by those engaged in the fishery, a fact which was implied in the very term, "whale fishery;" that in Natural History books of high anthority, of which a great pile was produced in

evidence, the whale was classed among fishes; and that whale oil had always been regarded as fish oil, and had been uniformly charged with duty as such. Counsel on the other side contended that the language of uneducated seamen should not be regarded as evidence, and that the classification in old books of Natural History, to which reference had been made, was founded on a very imperfect knowledge of the structure of the animals so arranged; but that if ancient records were to be referred to, he would go to one more ancient than any other—he would go to the Mosaic record of the creation itself, and would show that whales even there were mentioned distinct from fishes; for we read that "God created great whales, and every living creature that moveth, which the waters brought forth abundantly after their kind." The points of difference between whales and fishes were, he insisted, numerous, striking, and sufficient to render it needful to place creatures so essentially dissimilar in different classes. The fish breathes by gills, the whale by lungs; the blood of the fish is cold; that of the whale is warm; the heart of the fish has two compartments, that of the whale has four; the young of the fish is produced from spawn, that of the whale is born alive, and is suckled and tended by the mother with the most affectionate solicitude. Notwithstanding these arguments—which, so far as the Natural History question is concerned, are quite conclusive—the jury, after the trial had continued for three days, returned a verdict to the effect that the whale oil should be regarded as fish oil. There can be no doubt that such was the intention of the Act; the legislature, the very next session of Congress, amended the wording of it, in order that all ambiguity might for the future be avoided.

It is obvious, from these two examples, that the structure of the animal frame must form the only sure basis for our classification. That structure is adapted with the most consummate wisdom to the medium, whether air or water, which the animal is to inhabit, and to the conditions under which it is to live; and just in proportion as our knowledge is accurate with regard to each particular species, and comprehensive as regards its affinities to others, so will our classification be good or otherwise.

The principle just laid down is applicable to the whole animal creation. This has been spoken of as consisting of vertebrate and of invertebrate animals. To the genius of Cuvier, however, we are indebted for our first knowledge of the fact, that there exist differences among the invertebrate animals so great as to justify their division into three great groups, according to peculiarities in their nervous system. We are thus enabled to divide the entire animal kingdom into four great groups, or sub-kingdoms:—

I. VERTEBRATED animals, or *Vertebrata.*

INVERTEBRATE.

II. Soft-bodied animals, or *Mollusca.*
III. Articulated animals, or *Articulata.*
IV. Radiated animals, or *Radiata.*

We shall begin with the examination of those whose organization is the most simple, and gradually ascend to those in which it is the most complex. The radiated animals, therefore, have the first claim on our attention, and

in the next chapter you will find I shall introduce you to some members of this very ancient, though unseen fraternity. You may not, perhaps, have far to go for the introduction. More viewless than the ghost of Hamlet's father, you see them not, yet they are in multitudes around you. Some may even have done you the favour of selecting your bodily frame as their habitation, and, free alike from rent and taxes, laugh to scorn all attempts to serve them with "notice to quit."

CHAPTER II.

RADIATED ANIMALS.

"Think not that anything HE hath vouchsafed to create is unworthy thy cognizance, to be slighted by thee. It is pride and arrogance, or ignorance and folly, in thee so to think."—RAY.

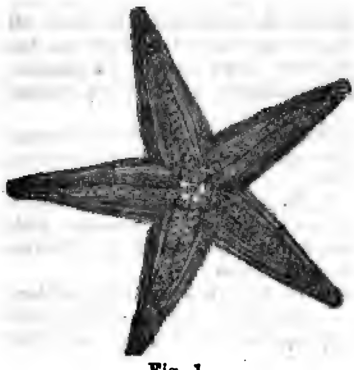


Fig. 1.

I HAVE placed at the beginning of this chapter the figure of a common star-fish, or "five-fingers." The limbs or arms are arranged like rays proceeding from a centre, and from this circumstance it is termed a "rayed," or "radiated animal." All with this rayed appearance have, of course, the same appellation, and, along with others, constitute the class RADIATA.

The rayed appearance is not, however, so obvious in many of these animals as in the star-fish. In the Sea Urchin we find it in the arrangement of certain parts of the covering, though not in the outline of the body. We can trace it in the bodies of the common elly-fishes, and in the parts surrounding the mouths of some of the Polypes. But there we are obliged to stop; we can follow it no further. In like manner the nervous system, so far as it has been traced, presents a radiated arrangement. But here also the clue which has guided our path for a certain distance eludes our grasp, and we meet animals in which no nervous system has as yet been discovered. The consequence is, that certain tribes have been placed in this division, simply because zoologists, in the present state of their knowledge, knew not where else they could be placed.

With more careful and extended research, some of the evils of this course have become apparent. It has been found that germs of aquatic plants, which in their young state have the power of moving about, have been classed as animalcules. Other vegetable productions the botanist has claimed as belonging to his dominion, and transferred them accordingly from the nimal kingdom; and zoologists of reputation assert that there are now

among the radiate animals some that ought to have a higher rank, and should, if justice were done to their merits, be promoted to the class Articulata, and some even to the Mollusca. In fact, the assemblage is, in many respects, a motley one; insomuch that a respectable star-fish of an established position in society, and wishing to keep his distance from equivocal companions, might be inclined to say, like Sir John Falstaff, "I'll not march through Coventry with them, that's flat."

I must, however, keep to our present classification until a more perfect be established, taking care to indicate the points where the progress of science, during the last few years, has suggested the idea of change. In this way the reader may consider that "coming events cast their shadows before," and that the best arrangement that can now be given should be regarded as provisional, not permanent. With this explanation we will now enter on the consideration of the Radiated animals. They are divided into four classes,* viz.:—

Infusoria, or Infusory Animalcules.
Entozoa, or Internal Parasites.
Zoophyta, or Polypes.
Radiaria, or Rayed Animals.

INFUSORIA, OR INFUSORY ANIMALCULES.

"Where the pool
Stands mantled o'er with green, invisible
Amid the floating verdure millions stray.
* * * Nor is the stream
Of purest crystal, nor the lucid air,
Though one transparent vacancy it seems,
Void of their unseen people."—THOMSON.

In casting our eyes over the earth and seas, the animal world that we actually behold constitutes only a part of the animal creation. Besides those that are hid in the sanctuary of the forest and the depths of the ocean, there are tribes which inhabit great caverns and subterranean waters, and that are specially adapted for dwelling in a world where darkness ruleth, and

Light "never comes, that comes to all."

And there are others—and to these our attention is now to be directed—that escape our notice, either by their own minuteness or by their dwelling-place. To this unseen world of animal existence this chapter is to be devoted; it comprises two classes of Radiate Animals—the Infusory Animalcules, which the microscope brings before our eyes, and the Internal Parasites, that live hidden from observation within the bodies of other animals.

I may mention, for the sake of some of my readers, that the word "animalcule" means a "little animal;" and that the term "infusory" has reference to their being easily procured by making an infusion of animal or vegetable matter, and allowing it to stand exposed to light and heat, such as the window of a sitting-room would afford. If a drop of the thick scum that may after a few days have gathered on the surface be placed between two plates of glass under the microscope, a busy world of animated existence will be revealed to view; and in that little film of water may be seen

* Sponges are not included, as naturalists are not yet agreed as to their real nature.

hundreds of delighted creatures swimming about as freely as if disporting in an ocean.

They are found, however, not merely in situations where decaying animal or vegetable matter would seem to supply them with food, but also in lakes, rivers, and even in wells of the purest water. They have been observed in great numbers, and in full activity, in a mountain spring at Lochnagar, Aberdeenshire, at an elevation of 3,700 feet; and at present we do not know the limit to their distribution.

Among them there is great disparity of size; the difference between the smallest and the largest being as great, proportionally, as between a mouse and an elephant. But the exceeding minuteness of the smallest, though science can reduce it to measurement and calculation, baffles our finite faculties, as completely as the vast distances and magnitudes of the heavenly bodies revealed by the astronomer. The measurement of one minute species (*Monas crepusculus*) is said to be $\frac{1}{2000}$ of a line.* Of such infusoria, a space not exceeding that of a single drop of water may contain five hundred millions of individuals! Two such drops might, therefore, have a population far exceeding that of all the human races now living on the earth!

We read of five hundred millions, and the words drop smoothly from our tongue, but how faintly does the mind take cognizance of the multitude expressed by those figures! It may assist my readers in forming some idea of its extent, if they estimate in what space of time the number of animalcules could be actually reckoned. I will suppose that the person counting them works only six days in each week, that he counts one in each second, and works twelve hours each day. At this rate it would take him thirty-seven years to complete his task.†

The first marvel about these diminutive creatures is their size; the second is their numbers; the third, and, to a reflective mind, perhaps the greatest marvel of the three, is their reproduction. This is very diversified. Some appear like buds or gemmules on the surface of the body of the parent, assume the characters of the species, drop off, and become detached and independent beings. Others, again, divide into two equal portions, by what is termed spontaneous fission or division (Fig. 2). The young exist in various states of progression, and undergo various changes, until they are able to swim about at large, select a new abode, put forth a new stem, and become the living parent of a fresh colony of bell-shaped blossoms—if such a term may be applied to a group of living animalcules.

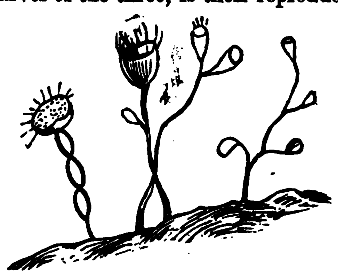


Fig. 2.

The fissiparous mode of reproduction is amazingly productive, and indeed far surpasses in fertility any other with which we are acquainted, not excepting the most prolific insects, or even fishes. Thus the *Paramecium aurelia* (which also propagates by *ova*), if well supplied with food, has been

* A line is the twelfth part of an inch.

† The exact period would be 37 years, 5 weeks, 0 days, 0 hours, 45 minutes, and 20 seconds.

observed to divide every twenty-four hours; so that in a fortnight, allowing the product of each division to multiply at the same rate, 16,384 animalcules would be produced from the same stock, and in four weeks the astonishing number of 268,435,456 new beings would result from a continued repetition of the process.

Perhaps the *Volvox globator*, of which a figure is annexed (Fig. 3), has excited, by its mode of reproduction, as much or more attention than any other species. The parent, to use the most popular and best understood expression, is a delicate green transparent globe, moving by means of minute hair-like bodies termed *cilia*, which cover the exterior surface. Smaller globes are seen in the interior, furnished with the same means of progression, and swimming freely about. At length the outer covering bursts; the young escaping through the fissure, enter on a wider sphere of existence; and yet, even at that moment, gemmules may be seen within them, which in like manner are destined to increase and come to maturity. Some authors regard the Volvox not as a parent and its young, but as a compound animal; but this question is one that need not at present be discussed.

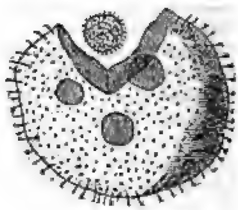


Fig. 3.

Besides these modes of increase, the *Infusoria* have that arising from the deposit of ova, or eggs. As the ditches in which the animalcules live dry up in summer, they perish; but prior to this the mature ova burst through the skin of the parent, and thus the last act of the creature's life is to provide for the continuance of the species, by depositing thousands of fertile germs. These are lifted up by the winds which scatter the dust—they are dispersed through the atmosphere, and float in the air, ready to assume the functions of active life so soon as they are placed in circumstances favourable to its development.

In the *Paramecium* already mentioned the eggs are excluded in masses. These are developed into young with great rapidity; these again lay eggs, not singly, but in masses; so that in two or three days their number surpasses calculation.

That particles of unorganized matter can, under any combination of circumstances, be converted into living atoms, such as these animalcules, is an opinion that has at times gained some degree of currency, but is altogether erroneous. The elaborate provision made for the continuance of these races, by the diversified modes of reproduction which have just been detailed, renders superfluous the theory of equivocal generation, and adds another proof to those we see everywhere around us, that the little and the great, as we are pleased to call them, are alike under the providential care of ONE in whose eyes such differences are of no account.

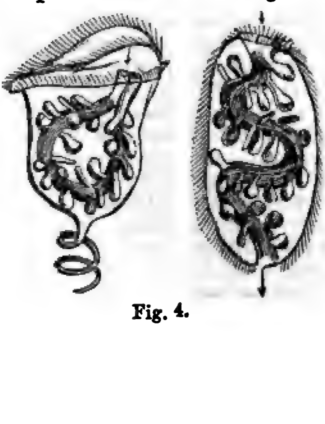


Fig. 4.

It is unnecessary to dwell long upon the classification of the *Infusoria*. They have been divided by Ehrenberg into two

great groups, comprising several genera: one group is distinguished by numerous internal sacs, or stomachs (see Fig. 4), as he regarded them; hence he gave them the name *Polygastrica*, or "many-stomached." The sacs or stomachs he rendered visible by dissolving some carmine or indigo, and placing it in the water with the animalcules: as they fed, the food deposited in these curious receptacles became apparent. This group contains those that are most diminutive in size, and most simple in structure. They are furnished with the little hair-like bodies called *cilia*, already mentioned, and by their action are impelled through the water, in which they find those nutritive particles on which they subsist. Some, I regret to say, indulge cannibal propensities, and contrive to gulp down a fellow-animalcule almost as large as themselves. Their movements would seem to be unaccompanied by fatigue, for they continue both by night and by day; and, like our breathing, or the circulation of our blood, seem not to depend on any act of volition.

The other group is of much higher structure, so much so, indeed, that their removal to the class of Articulated animals has been suggested. They have lobes surrounding the mouth; these lobes are fringed with *cilia*, which by their movement give to these parts the appearance of wheels in rapid motion. Hence Ehrenberg bestowed on them the name *Rotifera*, or "wheel-bearing." They can swim either slowly, or with considerable swiftness, in pursuit of their prey. Most frequently, however, they take matters very quietly, like gentlemen "who live at home at ease;" for, fixing themselves by the pincers shown in Fig. 5, they bring the *cilia* round their mouths into play; these cause currents in the water, and thus enable them to devour the unfortunate *Polygastrica* that come within the vortex. Twice have I now been summoned to lay down my pen, and witness the process. They have, for the better mastication of their prey, a singular apparatus of teeth, if it may so be called. It has been likened to an anvil, with a hammer on either side. These hammers can be brought into action in a moment: they must be very effectual implements, and are vigorously wielded.

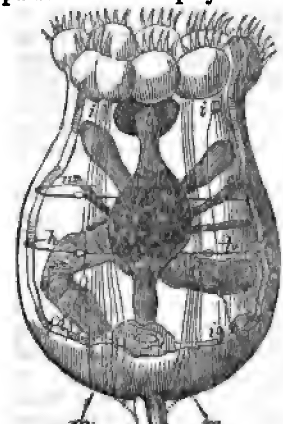


Fig. 5.

The rate of increase among the Wheel animalcules is greater than we know of among any other animals, their many-stomached relatives alone excepted. As an example, the *Hydatina senta* may be mentioned. Ehrenberg, we are told, watched during eighteen days successively an individual which was full grown when singled out, and did not die of old age, which proves this species to live more than twenty days. In from twenty-four to thirty hours this animalcule will deposit four ova, which will grow from the embryo to maturity, and bring forth their fertilized ova in the same period. An individual producing in ten days forty eggs, developed at this rapid rate of increase, would have on the tenth day one million of descendants, on the eleventh day four millions, on the twelfth day sixteen millions, and so continue to multiply.

Their tenacity of life is scarcely less remarkable than their numbers. They may be dried up until apparently dead, and again revived by the application of moisture. Fontana kept some of them two years and a half in dry sand, exposed to all the power of an Italian summer's sun; yet in two hours after the application of rain water they recovered life and motion.

When we muse upon this lowly region of animal life; reflect on the strange powers of increase with which its microscopic population is gifted, and the powers of endurance they possess, we cannot but be struck with the providential care that preserves them from destruction, and insures the continuance of the various species. And we may fairly infer that they serve important purposes, though we can but faintly trace them out. We cannot, however, err in saying, that by their feeding upon the decaying particles of organized bodies, they effectually assist in maintaining the purity of the waters; while at the same time, as their vast numbers compensate for their minute size, they furnish a large supply of food to other creatures dwelling therein.

CHAPTER III.

ENTOZOA; OR, INTERNAL PARASITES.

"Some get within him."—SHAKESPEARE.

THE word *Entozoa* means literally animals within or inside of other animals. It is applied to those internal parasites by which the bodies of man, and of animals inferior to man, are infested. Eighteen distinct species are said to live within the cavities and tissues of the human body. Every known animal is believed to have one or more species peculiar to itself. If this be correct, the number of species belonging to the Entozoa would exceed that of all the other species of animals now living upon the earth.

Their structure is extremely varied. Some are so simple that they appear like little bladders filled with a watery fluid; as, for example, that one which, when abundant in the pig, gives to the flesh of the animal the appearance termed *measly*. Others are so different from this, that some naturalists are of opinion they might with greater propriety be arranged with the *Annelids*, or true worms of the class Articulata. This species has been found in the human body, in the eye, the brain, the substance of the heart, and the voluntary muscles.

I shall do little more than refer to two or three examples illustrative of the variety of structure just referred to; but, as I would wish my readers to be assured that these despised creatures are worthy of investigation, I would beg their attention to what has been most truly and eloquently said by Professor Owen:—

"In creatures surrounded by, and having every part of their absorbent surface in contact with, the secreted and vitalized juices of higher animals, one might have anticipated little complexity and less variety of organization; yet the workmanship of the Divine Artificer is sufficiently complicated and

marvellous in these outcasts, as they may be termed, of the animal kingdom, to exhaust the utmost skill and patience of the anatomist in unravelling their structure, and the greatest acumen and judgment in the physiologist in determining the functions and analogies of the structures so discovered. What also is very remarkable—the gradations of organization that are traceable in these internal parasites reach extremes as remote, and connect them by links as diversified, as in any of the other groups of *Zoophyta*, although these play their parts in the open and diversified fields of nature."

Observations made on some species of Entozoa prove that their tenacity of life is not less than that already mentioned in the *Rotifera*. A minute worm that attacks wheat, and is essentially the same in point of structure with some of the internal parasites, has been dried, and, after periods of from four to seven years, revived by the application of moisture. Their power of enduring the extremes of heat and cold is very remarkable. A worm has been seen to exhibit strong contortions—evidently vital motions—after having been subjected for an entire hour to the heat of boiling water, along with a cod fish which it had infested. Rodolphi states that other Entozoa, which attack herrings, are annually sent with these fish to Berlin, hard frozen and packed in ice, and, when thawed, exhibit unmistakable signs of restored vitality. These observations, it should be borne in mind, are made on the mature *Entozoa;* still greater capabilities of endurance must naturally belong to the eggs, or *ova*.

This circumstance, and the extreme abundance in which the ova are produced, will enable us to account for their retaining dormant powers of life until placed in circumstances suitable for their development. Let us now turn to an example of one of their diversified modes of reproduction.

There is a kind of parasite worm known in these countries as the Tape-worm (*Tænia solium*). It is found in the human intestines, and attains the length of three or four yards; occasionally even more than this. Now one curious fact about it is, that the very same species that infests the natives of Great Britain infests also the Dutch and Germans. Another species, *Botriocephalus latus*, is peculiar to the Swiss and Russians; while the inhabitants of the French provinces adjoining Switzerland possess the unenviable distinction of being infested with both. It is strange that these creatures should thus be restricted to certain countries, as they are, by their mode of life, exempt from all "the skyey influences." Perhaps some of my readers may be inclined to speculate on this very singular fact, and infer that honest John Bull must have something about him akin to "the stuff" that Dutch and Germans are made of, when parasites of the same species attack them in common, and avoid the Russians and the Swiss. But this were to "reason too curiously," for an Englishman might be infested with the Tape-worm of Russia, if he became for a long enough time resident in that country.

The head of the Tape-worm is furnished with suckers and recurved hooks, so that it can retain a firm hold. Like the root of a plant, it imbibes the nutritive juices required for the support of the entire structure. Each of its numerous joints possesses within itself the means of producing thousands of fertile ova. These joints break off, separating from the stem, as branches heavy with ripe fruits from a richly-laden tree. But a strange mode of reproducing them is provided. The joint next the head divides into two *joints; each of these* expands, and then divides in like manner; so that the *egg-producing segments* resume in time their former proportions, and thus

one head may outlive successive generations of the other parts. "Is there any one," says Professor Escright, "who upon the contemplation of this wonderful apparatus, and the extraordinary results of its agency, can for a moment imagine that it is without an object or an end?" The Tape-worm is not produced by chance: no atoms of matter shaped themselves into the living animal, according to the hypothesis of equivocal generation. In all its wonderful details, the humble worm declares its Great Artificer; and Science stands—as true Science ever will stand—the handmaid of Religion.

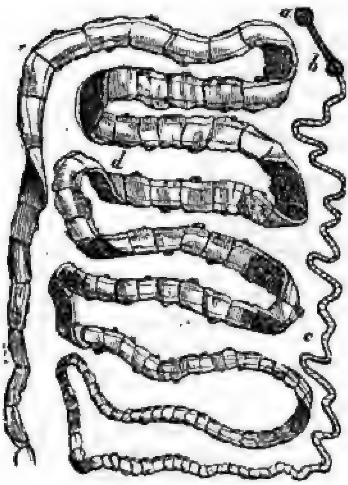


Fig. 6.

Among the Entozoa we meet with some strange, and, to our eyes, fantastic forms. There is one diminutive fellow (*Diplozoon paradoxum*) that attaches itself to the gills of the bream; and though only about a quarter of an inch in size, exhibits, like the celebrated Siamese youths, two distinct bodies united by a narrow band. Others have the appearance of possessing two mouths, and from this circumstance are known by a scientific term (*Distoma*) expressive of this peculiarity. One of these supposed mouths is in reality a sucker, and enables the creature to retain its hold. A species of this genus is unhappily too well known to the farmer by the name of the "liver-fluke;" and though he may be ignorant of facts relating to the abundance and the vitality of the ova, he knows from experience that he must remove his sheep from waters and pastures where others have been infected by "the fluke," if he would keep them safe. The genus *Distoma* embraces many species, very different in size and habit. Listen to the account of the transformations of one species, as observed by Steenstrup, and published in one of the volumes of the Ray Society.

It is well known that the stagnant pools in which fresh-water shells (particularly the *Lymnea* and the *Paludina*) are found, contain an innumerable variety of minute animals of various kinds. Among these is a small worm, known to naturalists under the name *Cercaria*, and looking like a diminutive tadpole, with a long tail, a triangular head, and a large sucker in the middle of the body.

If we watch these worms, which always abound in the neighbourhood of the shells mentioned, we find them after a time attaching themselves, by means of their sucker, to the body of the Mollusca. The tail now falls off, the worm buries itself in the mucous substance of the snail, and there remains nearly motionless, like a caterpillar on its transformation into the pupa. If we remove the little creature from its retreat, we find it now changed into a *Distoma*. The former animal was but the larva of the present one.

What, now, is the origin of the *Cercaria*? If, at certain seasons of the

year, the viscera of one of the Mollusca referred to be opened, we find a quantity of worms of a peculiar form. The cavity of their bodies is filled with a mass of other little worms which a practised eye easily recognizes as young *Cercaria*. The worm that contains them is but their living envelope, and on this account has been called the *nurse*. These *nurses*, strange to say, are the offspring of other nurses, which have been produced directly from the eggs of the *Distoma*. If this be so, it takes four generations and one metamorphosis to bring round again the likeness of the perfect animal from which they all originated; in other words, the parent would find no resemblance to himself in any of his progeny until he arrived at the great-grandson!

It would be rash to affirm that every species of *fluke* passes through a similar series of changes, for we must not venture in Natural History to reason from analogy further than to say that such an inference is probable. Every species must be carefully investigated by itself before we can be said to know its history. That this family (*Trematoda*) exercises a wide-spread influence is certain. They are found in the eyes of many animals, as well as in other organs. In the eyes of fishes they are particularly abundant. The little white specks which may sometimes be seen in the eyes of the common fresh-water perch are, in fact, minute animals belonging to this group of zoophytes.

Look well about the moist stones on the sea-shore, and you may possibly notice a little animal, about an inch long and a quarter of an inch broad, gliding over their surface, and looking like a bit of leather cut from a lady's glove and endowed with life. It is a *Planaria*. Some of these are found in fresh water, some in salt; they are carnivorous in their habits, and vary in colour from time to time, according to the colour of their food, so that the same individual may appear red one week and green the next.* We cannot say of them that they eat until they are "like to burst," for so voracious are they that they actually *do* burst from their excessive greediness. The strangest thing, however, about them is the manner in which the body breaks into fragments, and each part becomes a perfect animal. Sir John Dalzell, in speaking of one of them, says,† "But, independent of propagating by eggs, the *Black Planaria* is privileged to multiply its species in proportion to the violence offered to its otherwise delicate frame. It may almost be called immortal under the edge of the knife. Innumerable sections of the body all become complete and perfect animals: if the head be cut off, a new head replaces it; if the tail be severed, a new tail is acquired." On a summer evening, when Sir John was looking at one of these animals, he saw a strange performance—the head was made to separate itself from the body, and crawl away—a feat equal to that of the "Headless Horseman of Sleepy Hollow," when he flung his head at the terrified Ichabod Crane. Thus it is that the facts of Science are more wonderful than the creations of Fancy. The truth is stranger than the fiction.

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* Darwin found eight species of terrestrial Planariæ from within the tropic to lat. 47° south. They were striped with bands of gay colours, and were found about decaying timber, on which they appeared to feed.

† Observations on Planariæ, page 31. Edinburgh, 1814.

CHAPTER IV.

ZOOPHYTES.

"They that go down to the sea in ships, that do business in great waters:
"These see the works of the Lord, and his wonders in the deep."—PSALM cvii. 23, 24.

MANY of the animals belonging to this division resemble flowers, not only in form, but in the brilliancy and variety of their colouring. "Moreover," says Dana,* "a large number of Zoophytes are so like the trees and shrubs of land vegetation as to have deceived even the philosopher till near a century since. The mosses and ferns of our woods—the lichen and mushroom—the clump of pinks—the twig and spreading shrub—have all their counterpart among the productions of the sea. The ocean-grove is without verdure, yet there is full compensation in its perpetual bloom; for each coral branch is everywhere covered with its star-shaped animals, the 'coral blossoms.'"

Ellis, a London merchant, was the first to establish their true character. Attracted by their beauty, he was led to examine them with the microscope, and saw evidence in their texture that they were more of an animal than of a vegetable nature. His "suspicions," as he modestly terms them, were communicated to the Royal Society in 1752. After an interval of two years, during which he had confirmed the accuracy of his former observations, his views were more fully explained to the same body; and in 1755 he published his justly celebrated work on the *Natural History of the British Corallines.*

The observations of preceding naturalists had, to some extent, prepared the public mind for the reception of the views advocated by Ellis. But Linnæus was then living, in the very zenith of his reputation, "the observed of all observers," and looked up to by his followers as the prince of naturalists. By him the new opinions were received with [illegible] and finally, led captive by his rich and poetic imagination, he decided [illegible] were intermediate in their nature between plants and [illegible] the functions of animal and vegetable life combined; or, [illegible] "vegetables with respect to their stems, and animals [illegible] florescence."

After these introductory [illegible] the meaning of the [illegible] is easily understood, and easily [illegible]ered. It is deriv[illegible] words, one signifying an "ani[illegible] other a "plant." [illegible] fore, as regards external appea[illegible] animals that h[illegible] growth; and it reminds us, at [illegible] time, that even ph[illegible] period looked upon them as com[illegible] their structure an[illegible] table life.

But, although the external res[illegible] objects belongin[illegible] table kingdom is so striking, th[illegible] likeness [illegible] "Each of these flower-animals has [illegible] a cavity [illegible]

* On the Structu[illegible]

digest food; and the appendages that look like petals are organs fitted either for securing their prey, or for some other animal function. Some species have actually been fed, and the process of digestion watched by the naturalist. They are not always invisible animalcules, as has been the common impression; on the contrary, many of the most common varieties are half an inch in diameter, while others are one, two, and three inches, and others are a foot to eighteen inches.*

They present a great variety of form, sometimes aping that of common domestic articles, such as a drinking glass,† or a bottle-brush;‡ at others assuming the appearance of delicate lacework, more perfect and more wonderful than any that was exhibited within the Palace of Glass in 1851. This lace, spread over the leaves of some of our larger sea-weeds, shows, to use the words of an old writer,§ "how the needle of Nature delighteth to work." Some not only resemble flowers, but bow their living blossoms,‖ as if in homage to the dredger who has removed their beauties from the ocean depths, and revealed them to the gaze of sentient beings.

"The marigold, that goes to bed with the sun,
And with him rises weeping,"

is represented, with all its class, by living inhabitants of the sea, not less beautiful in shape or colouring; and that tree, whose pensile branches are associated with human affections and sorrows, has its miniature representative, called the "sea cypress." ¶

Zoophytes of these, and all other existing forms, are arranged by naturalists in four principal groups or orders. The likeness to various members of the vegetable kingdom is the prevailing characteristic of the first three of these. In the other a higher grade of structure prevails, and establishes its near affinity to creatures from which it is widely removed in our present classification. Let us now give our attention to each of these four orders in succession.

ORDER I.—HYDROIDA.

"New buds and bulbs the living fibre shoots
On the lengthening branches and protuding roots;
Or on the father's side, from bursting glands,
The adhering young its nascent form expands."—DARWIN.

Hydroida simply means "hydra-like," or resembling the hydra, a fabled monster of Lake Lerna, with fifty or a hundred heads, of which no sooner was one cut off than two sprouted out in its place. The real hydra, however, is a creature found pretty generally in ponds and ditches, though not

* Dana.

† "When at rest it (*Lucernaria fascicularis*) assumes very much the form of a common drinking glass, and is exceedingly conspicuous from its beautiful rose tint."—*Templeton.*

‡ "The polypidom (*Thuiæria thuja*) retains throughout its whole growth the appearance of a bottle-brush."—*Johnston.*

§ Sir Thomas Browne, a learned antiquary and physician, born 1605.

‖ *Corymorpha nutans.* "Its head gracefully nodded (whence the appropriate specific appellation given it by Sars), bending the upper part of its stem."—*Forbes and Goodsir.*

¶ Sertularia cupressina.—*Ellis.*

in all localities; and the true history of its birth, its powers, and its habits is more strange than any classic fiction."

Look at the under side of the leaves of the common duckweed of our ponds and ditches, and you will, perhaps, find on some a little bit of jelly, not larger than half the size of a pea. Place it in a glass vessel filled with water, and if you have found the hydra (Fig. 12), it will, after a time, spread out its long hair-like tentacula, or feelers. Woe to the little creature that comes in contact with them! It becomes paralyzed by their touch, and is drawn helplessly into the mouth of the hydra, and devoured.

Fig. 7.

Some of the minute crustacea, that live in fresh water, now and then escape, as if their shelly covering had, in some degree, afforded them protection. But worms, which, under ordinary circumstances, bear severe wounds, have been observed to die after being bitten by the hydra, though afterwards removed from its grasp.

To Trembley, a naturalist of Geneva, we are indebted for our first information respecting this creature. When, about the year 1744, he made known its wonderful properties, the announcement created the liveliest sensation of astonishment, and his alleged facts were, by many, regarded as impossible fancies. But all his discoveries were speedily confirmed; and admiration at the skill and perseverance with which his investigations were pursued succeeded to the previous distrust.

Perhaps no part of their history seems more strange than their power, not only of enduring injuries, but of multiplying under the process which threatened their destruction. This was tested by Trembley by many strange experiments. One was cut into halves, and soon each half became a perfect hydra. One was divided into three parts, and in three or four days, in summer, the tail had produced a head, the head a tail, and the middle part a tail at one end, and a head at the other; and even before completion they sometimes gave out buds, which rapidly assumed the likeness of the parent. From forty parts forty hydras were formed. The body slit open soon unites again, even if each part is previously extended like a flat ribbon. One hydra pulled into the body of another unites with it, so that they form but one animal. And two may be made to change heads, for the head of the one may be engrafted on the body of another. Among such animals the question of personal identity would become a very puzzling one; and degrees of consanguinity or relationship would perplex the genealogist.

It has been truly remarked, that "no one has ever written the complete history of any one animal." If we rake together all that has been recorded of the hydra, we have a long and marvellous record; yet it is not complete: new points of inquiry are continually suggested, showing that to understand in all its fulness the history of even the humblest zoophyte belongs not to one whose duration is so brief, and whose faculties are so limited, as those of man in his present state of existence. Let us, therefore, move onwards.

The hydra has the power of changing its place at pleasure, and its entire body is naked. In both respects it differs from the members of another family. Their aspect is that of a number of tubes, from a couple of inches

to a foot in length, attached to a common base, and often more or less twisted together. From these tubes the name *Tubularia* is applied to such animals. From each tube a head of a beautiful red colour projects, looking like an animated flower. These heads or blossoms drop off, the tube remains bare and unsightly, like a tree reft of all its floral glory; yet ere long, from that naked stem, a new head is developed, and the living blossom waves once more its tender filaments, and seeks again the food on which it lives.

The great majority of the zoophytes belonging to the present order are, however, those which, in little tree-like tufts, decorate the shells of the oyster and the scallop, are attached to stones, or cluster upon the fronds of the large sea-weeds. These are grouped together under a name (*Sertularidæ*) which is derived from a Latin word (*sertula*), signifying a little wreath or garland. Hogarth, our great moral painter, thus writes to Ellis respecting them:—"As for your pretty little seed-cups, or vases, they are a sweet confirmation of the pleasure Nature seems to take in superadding an elegance of form to most of her works, wherever you find them. How poor and bungling are all the imitations of Art! When I have the pleasure of seeing you next, we will sit down—nay, kneel down, if you will, and admire these things." With these striking words Dr. Johnston commences his *History of British Zoophytes*, and adds, "He must indeed be more than ordinarily dull and insensate who can examine them without catching some of the enthusiasm of the artist. They excel all other zoophytical productions in delicacy, and the graceful arrangement of their forms; some borrowing the character of the prettiest marine plants, others assuming the semblance of the ostrich plume; while the variety and elegance exhibited in the figures and sculpture of their miniature cups and chalices are only limited by the number of their species."

How shall I describe the growth and nature of these productions? Suppose a miniature tree, its branches covered with little cells, and a minute animal spreading out from each cell its tentacula, feelers, or arms—by whatever name you term them—and seizing its allotted food. If touched or alarmed, it can shrink into its cell. Yet call it not the inhabitant of that asylum to which it has retreated. To do so would convey a wrong idea. It would imply that a living creature had sought safety in a lifeless cell, whether formed by itself or not; it would suggest the idea that the little animal, or "polype," as it is called, is one thing, and the cell another and a distinct thing. But this is not the fact; the polype, the cell, and all the polypes and cells are spoken of as one zoophyte (Fig. 8). All the polypes are united together by the pith or *medulla* of the stem and branches. Each, while feeding itself, is procuring food for all; and the entire may be regarded as one organism, acquiring sustenance by the joint action of, perhaps, a thousand mouths. The repetition of an organ indicates a humble rank in the scale of animated existence. It

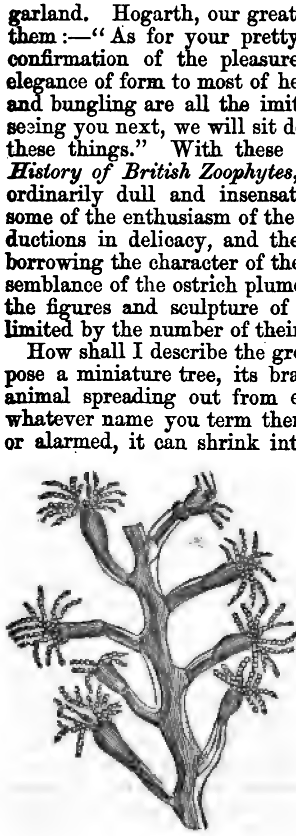

Fig. 8.

did so in the many stomachs of the polygastric animalcules; it does the

same in the multitudinous mouths of the *sertularian* zoophytes. But humble as their rank appears to be, a providential care is manifest in the reproduction of the young, and the continuance of the species. The young are brought forth both from buds and eggs. "By the former the polype extends its individual life, while by the latter the species is multiplied and continued." The most populous growth sprang originally from a single polype, and grew by the development of buds. Amid its branches, at certain seasons, cells of larger size and of a peculiar shape are observable (Fig. 9). These contain the ova, or eggs, which, gifted in their more advanced condition with powers of locomotion, diffuse themselves through the waters of the ocean, and each becomes in turn the founder of a colony, more populous than the greatest city over which the eagles of imperial Rome ever floated.

Fig. 9.

On such subjects our ideas fall far short of the actual truth. Hear the statement of Dana, geologist of the United States exploring expedition, as given in his work on the *Structure and Classification of Zoophytes*. "The first polype with which the zoophyte commences thus gives out a bud, and this another, and so a succession is formed, and the little stem is gradually lengthened; branchlets grow out, and the plume or miniature tree is finally completed. The whole may be the work of a few weeks or months, though they usually continue budding and growing for some years. Before the zoophyte has reached its limits in size, the number of polypes becomes immensely large (Fig. 10). In a single specimen of Plumularia (*P. angulosa*), collected by the author in the East Indies, there are about twelve thousand polypes to each plumose branch; and as the whole zoophyte, three feet long, bears these plumes on an average every half inch, on opposite sides, the whole number of polypes is not short of eight millions, all the offspring of a single germ, and produced by successive buddings."

Fig. 10.

Many of these creatures possess the power of giving out a brilliant phosphoric light. They do so when struck or otherwise irritated, appearing like so many diamond sparks. Every polype seems to have the power of emitting or withholding the light at pleasure; and when the trawl of the fisherman is drawn at midnight, or groves of the large tangle are disturbed by the dredger, the

phenomenon is eminently striking and beautiful. Crabbe, whose poetry evinces minute accuracy in all its delineations of nature, animate or inanimate, has described this appearance;* but to all my young friends who live near the coast I would say, "Go and see it for yourselves."

It has been already stated that the present order derives its name from the polypes having a resemblance to the hydra, the species most celebrated. But other polypes present a star-like figure, and from this circumstance they are formed into a group or order distinguished by a term expressive of this resemblance, namely, "Asteroida." Of these I shall speak in the next chapter.

CHAPTER V.

ASTEROIDA.

"There, with a light and easy motion,
The fan-coral sweeps through the clear deep sea."

ASTEROIDA are the second order in zoology, and are found only in the sea, and never as detached individuals, but as a community united together by a living membrane, containing the cells, within which the polypes retreat at pleasure. Fig. 11 will better explain this than any description.

The common English names applied to different groups of this order are expressive of their general appearance. Thus we have sea-pens, sea-rushes, sea-paps, dead-man's-hands, sea-shrubs, and sea-fans. The individuals of one family (*Pennatulidæ*), comprising the sea-pens and sea-rushes, are at times brilliantly luminous, emitting a phosphoric light whenever they are touched or in any way irritated. On some parts of our coasts these animals are tolerably plentiful; at other parts they are altogether unknown. The most common species of sea-rush (*Virgularia mirabilis*) is from six to ten inches in length, and presents a very attractive appearance, but faintly indicated by Fig. 11, exhibiting one portion of the stem and its plumules magnified.

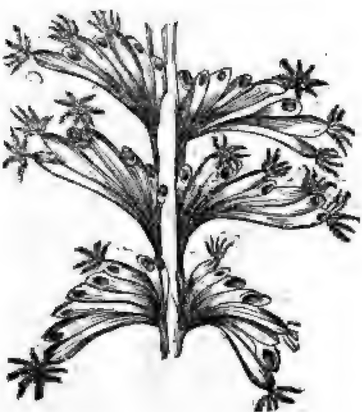

Fig. 11.

In the broad-spreading lobes of the sea-fan the living membrane is spread over a framework composed of a flexible substance resembling horn, so that this zoophyte bends beneath the force of

* "See, as they float along, th' entangled weeds
Slowly approach, upborne on bladdery beads;
Wait till they land, and you shall then behold
The fiery sparks those tangled frônds unfold—
Myriads of living points; th' unaided eye
Can but the fire, and not the form descry."
The Borough, Letter IX.

waves and currents, just as the hosier does before the tempest, and thus survives unhurt. The red coral of the Mediterranean Sea resists, in virtue of its short stout branches; and the iris unites the strength of the calcareous skeleton with the flexibility of the corneous one by a curious union of both substances, arranged in alternate joints. Our illustration (Fig. 12) exhibits the exterior, with its numerous star-shaped polypes; and the singular structure which the interior of the stem presents, when part of the fleshy covering is removed, is shown in Fig. 13.

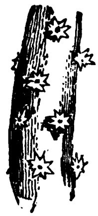

Fig. 12.

Fig. 13.

HELIANTHOIDA

is the third order, and denotes that the animals it includes bear a resemblance to such flowers as the daisy, the marigold, and others, which the botanist terms "compound." The little rock-pools round our coast furnish examples of the common Sea-anemone (*Actinia mesembryanthemum*), and this will suffice to illustrate some of the most striking peculiarities of structure.

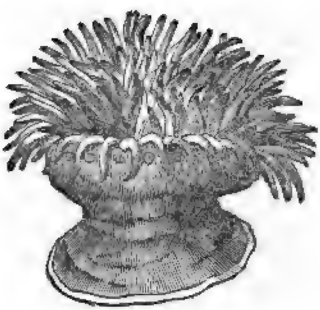

Fig. 14.

At low water it appears a fleshy hemispherical substance, totally inert, and adhering to the rock. But with the returning tide it is roused again to activity, expands its disc, and presents once more the appearance of a "living flower." (Fig. 14.)

When disposed to change their place, they have different means of doing so. They can detach themselves from the rock to which they are attached by the base, and glide along until they reach the spot they wish.

As to food, they are not particular—any marine animal, not too bulky, is sure to be acceptable: an unwary shrimp or crab, seized by means of the adhesive tentacula, may struggle in vain to escape, and is soon committed to the capacious stomach, from "whose bourne no traveller returns." The shells of a cockle, reduced into a soft consistence, are rejected from the stomach after a lapse of several hours, when all the nutritious portion of their contents has been extracted. The Sea-anemone, therefore, runs no risk of dying of indigestion.

The Sea-anemones possess a wonderful power of enduring abstinence, and surviving mutilation. "They may be kept," says Dr. Johnston, "without food for upwards of a year; they may be immersed in water hot enough to blister the skin, or frozen in a mass of ice, and again thawed; and they may be placed within the exhausted receiver of an air-pump, without being deprived of life, or disabled from resuming their usual functions when placed in a favourable situation."

The facts now mentioned give an idea of some of the structural peculiarities of the Sea-anemones. But we must return to them again, and view them under other aspects; for to this order belong the principal builders of those vast structures, the coral islands of the Pacific.

CHAPTER VI.

CORAL ISLANDS AND THEIR BUILDERS.

> "Trees of the deep, and shrubs, and fruits, and flowers,
> As fair as ours,
> Wherewith the sea-nymphs love their locks to braid."
>
> SOUTHEY'S *Kehama*.

I WOULD now wish to transport my readers, "by my so potent art," from this region of fog, and rain, and sleet, to one of the sunny isles of the Pacific, with its azure sky, its beach of glittering white sand, its snowy breakers, and the "deep and dark blue ocean" beyond. The land is but a narrow, though a verdant strip—it is annular, or ring-shaped, in its form—decked with the foliage of lofty cocoa-nut trees, and the central part is occupied by the smooth water of a lake, or lagoon, communicating with the sea. We have reached a coral island. Let us gaze into the waters around, rich in lovely forms of animal life.

Some species of zoophytes select the tranquil lagoon for their abodes; others prefer the sea, and even make choice of that portion where the surf is greatest. This may seem "passing strange," and yet it is a well-ascertained fact. The great mounds of living corals (*Porites* and *Millepores*) occur exclusively on the extreme verge of the reef, which is washed by a constant succession of breakers. Such is the case at the island known as Keeling Atoll. At the Maldiva Atolls, as we are informed by Darwin, the outer margin consists of living corals, and here the surf is so tremendous, that even large ships have been thrown, by a single heave of the sea, high and dry on the reef, all on board thus escaping with their lives.

Writers seem almost to vie with each other in extolling the beautiful appearance of the zoophytes by which these reefs are constructed. "Quand la mer est calme, c'est un spectacle admirable que de voir les belles couleurs veloutées qu'ils étalent: elles imitent les tapis les plus riches et les plus variés," is the language of Le Sueur. "Where," says Ehrenberg, in speaking of those of the Red Sea, "where is the paradise of flowers that can rival in variety and beauty these living wonders of the ocean?" "There are few things," says Captain Basil Hall, "more beautiful to look at than these corallines, when viewed through two or three fathoms of clear and still water. It is hardly an exaggeration to assert that the colours of the rainbow are put to shame, on a bright sunny day, by what meets the view on looking into the sea in those fairy regions." Like many other objects of human admiration or desire, they, however, look most attractive at a little

distance. If removed from the water their charms, both of form and colouring, disappear, as if some malignant spirit had changed to slime the sea-born blossom we had snatched from its native bed.

Among those flowers are many that remind us of the *Sea-anemone* of the little rock-pools of our own coast. Though different in species, and also in the genera to which they belong, they still retain a family likeness. Most of them are not solitary individuals like those at home, but, as if impressed with the truth of the old adage, "the more the merrier," they have established a social fraternity with a community of interests, and live very harmoniously together. The annexed figure will serve to show their sociability; and it might be exemplified by many other examples, in which the individual polypes are differently arranged, and construct their common buildings, or common skeleton, if that be a better term, after a different fashion.


Fig. 15.

If we could suppose that any of these living blossoms were admirers of Shakespeare, we might fancy they had profited by Lady Macbeth's advice, "Look like the innocent flower, but be the serpent under it;" for some of them sting rather severely. Mr. Darwin mentions that he was a good deal surprised at meeting two species of *Millepores* possessed of this property. When a branch was applied to the face the pain was instantaneous; it increased after a few seconds, remained sharp for some minutes, and was perceptible for half an hour afterwards. The sensation was as bad as that from a nettle. It may diminish our wonder that such effects could be produced, when we learn that an apparatus of darts, or spicula, and poison bags, has been observed even in some of our native species (and also in the *Hydra*), but their powers are feeble compared with those of their tropical cousins. The scientific name for the common Sea-anemone of our coast is *Actinia*, a word which signifies "a ray." The term *Actinoidea* has been applied to the group in which all those zoophytes that resemble the *Actinia* are included. Some do, and some do not, possess the power of secreting coral. No peculiarities of structure, either external or internal, distinguish the coral-secreting polypes from the others. The coral itself, in the living zoophyte, is, in general, wholly concealed within the polypes, and is in no part external.

On looking at any collection of corals, we are impressed with the idea that some of them, from their external appearance, may have been caused by the labour of a single polype, while others, from the multitude of little cells or depressions which they exhibit, may be the joint production of a multitude. And this, our untaught surmise, will agree with the actual facts; for, in the marine world of busy architects whence the corals were brought, there are some that are Lilliputian in their size, and others that comparatively belong to the kingdom of Brobdignag. Some are solitary polypes, resembling the soft Actinia, though of larger dimensions; others are grouped together in living myriads—the progeny of a single germ. On some of the branching corals we sometimes notice hundreds of little cells on a single branch. Each of these marks the position occupied at one time by a polype, so that, by count-

ing them, we may, if we please, ascertain the number of flower-animals by which the branch was constructed.

The principal coral builders are to be found within twenty-eight degrees of the equator. Some of them have such a partiality for warmth, that they keep to that portion of the sea where the temperature is so high as eighty to eighty-five degrees of Fahrenheit, and might be looked for in vain where the thermometer is lower than sixty-eight, that being the winter temperature of the sea towards the outskirts of the region where coral reefs abound. Other species may be sought in more temperate regions, such as the waters of the Mediterranean; and some in northern seas, and at a depth of several hundred feet.

In general, however, the range of depth is singularly small; it is especially so in some that are the most effective coral builders. Most of those belonging to the Madrepore and Astræa tribes are found within sixteen or twenty fathoms of the surface. This cannot be occasioned by the diminution of temperature; it may be attributed in part to the decrease of light; but more, perhaps, to that of the air diffused through the water. The conditions needful for the vigorous growth of coral appear, however, so complex, and are at present so imperfectly understood, that changes not obvious to our senses might destroy the coral reefs in one area, and give occasion to their growth in another. Hence, as Darwin has remarked, "the Pacific or Indian Ocean might become as barren of coral reefs as the Atlantic now is, without our being able to assign any adequate cause for such a change."

A bank of coral, comprising species belonging to several genera, offers a curious subject for comparison in the mass of what is dead, and what is still living. Mr. Dana, who has had ample opportunity for such observations, remarks, "An Astræa dome, twelve feet in diameter, although solid coral through its interior, is alive for only one-half or three-fourths of an inch from the surface; so that the live portion, could it be separated, would form a thin hollow hemisphere. Even the branching Madrepores are usually lifeless along the axis of the branches; and in the Porites, whether forming a branch half an inch in diameter, or a glomerate mass of twenty feet, the polypes do not extend within beyond two lines. The interior is dead coral, the former animal tissues of which have dried up."

The branching or columnar coral zoophytes are not only dead along the axis, but they become *throughout* dead at the bottom, after attaining a certain height. The addition of an inch at the apex is death to an inch below. Some Gonipores, which grow in columns two feet or more in height, have a head of live polypes, a capital to the column, of only two or three inches.

Upon this principle of growing and dying depend the vast power and geological influence of the coral polype. But a few lines in height themselves, they would otherwise be limited in their coral-making to as many inches at the most, and what is now styled the coral-garden would be but a bed of mosses or incrusting lichens. Like the sphagnous moss of a peat swamp, coral zoophytes continue growing at the top, with none the less luxuriance, though supported on several feet of a lifeless trunk. Death follows on, "*æquo pulsat pede*" up the stem of a zoophyte, "*regumque turres.*"

Having thus glanced at the habits and distribution of some of the coral

polypes, and the manner in which life and death are mingled in their dwelling-places, we are prepared to turn our attention to the numerous islands and reefs of the Pacific and Indian Oceans, and inquire how, under the dispensations of Providence, the power of consolidating structures so vast can be exercised by beings so feeble? How, by the mere abstraction of particles of carbonate of lime from the sea water, can these soft-bodied creatures build up reefs and islands, the marvel of the navigator, the theme of the poet, the object of the highest philosophical interest to the geologist and to the zoologist? To Mr. Darwin belongs the honour of propounding a theory which has met with general acceptance among men of science, and which is applicable to all the diversified forms of coral reefs and islands. From an extended series of observations, he feels himself warranted in asserting—

1st. That the polypes most efficient as coral-builders cannot exist at a greater depth than twenty or thirty fathoms.

2nd. That the polypes thrive best at the outer edge of the reef, where the water is highly aërated, and where food is most abundant.

3rd. That the Pacific and Indian Oceans have extensive areas both of elevation and of subsidence as regards the crust of the earth; and these areas, or bands, are alternate.

Taking for granted that those conclusions are correct, let us see in what manner they are applicable to the different kinds of coral formations.

Let A, in the annexed diagram, represent the highest point of an island, in a part of the sea where the depth does not exceed twenty or thirty fathoms. In such a case the labours of the polypes would, in time, construct a bank, or wall of coral, marked C, which would rise to the surface of the water, and form a fringe round the island. This would be termed a "fringing reef." Strictly speaking, such reefs are never attached to the shore, for the water is there turbid, and, as already stated, the corals flourish most at the outer edge.

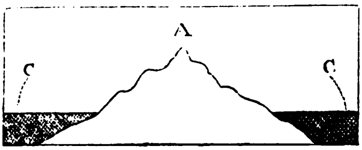

Fig. 16.

If now the island sank gradually, at a rate not greater than that at which the polypes could work upwards; or if it experienced a series of subsidences, subject to the same limitation, the outer margin would regain the surface, and its living mass, bathed by the ceaseless surf, luxuriate above the mass of lifeless coral beneath. The island would now seem reduced in size; the edge of the coral bank would form a barrier to ships approaching the land. This would be termed a "barrier reef;" and between the reef and the shore would be an expanse of still water (Fig. 17).

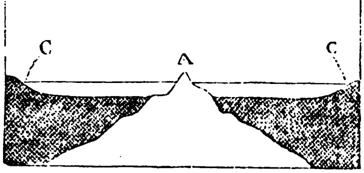

Fig. 17.

Let these operations proceed still further; the island would become entirely submerged, and in time surmounted by the coral formation, which, increasing as before most rapidly at the outer edge, would contain within

its bosom a shallow lake (Fig. 18). This would be the lagoon; the coral island would be that known as the Atoll, or Lagoon island.

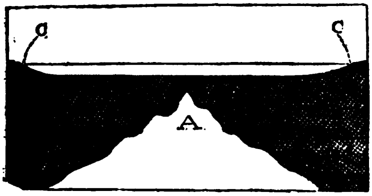

Fig. 18.

Where the fringing reef occurs, it may be considered as indicating that the crust of the earth underneath is stationary, or has risen. The barrier reef, on the contrary, indicates subsidence; and the Atoll may be regarded as a monument raised by coral builders over land entombed beneath the ocean, as if

"To mark where an *island* had been."

All the active volcanoes scattered over the Pacific and Indian Oceans are found within the areas of elevation; the Atolls within those of subsidence.

During its progress upward, the coral reef has its vacant spaces filled up by the *débris* carried thither by the waves, and occasionally by dead coral. Occasionally, however, large quantities of carbonate of lime—the products of decomposed shells and corals, and produced by chemical precipitation—fill up the interstices, and form in the coral reef masses of very compact limestone. Branching corals, and other organic remains, may thus be inclosed in a solid cement, and become portions of a rocky mass. In general, the dead coral is protected from injury by minute incrusting corals. These "make the surface their resting-place as soon as it is laid bare, and go on spreading and covering the dead trunk, and so prevent the wearing action of the sea. The Madrepore may thus continue to enlarge beyond its adult size; the Caryophyllia may multiply almost endlessly its cylindrical branchings, although the living animal but tips the extremities of each; for protection is given at once, when needed, and the polypes die only to leave the surface to other forms of life more varied, and no less strange."*

From the variety and succession of animal life, let us contemplate its amount at only one period, and limited to only a single coral of the mighty pile. "The domes of the Astræas are of perfect symmetry, and often grow to a diameter of ten or twelve feet without a blemish. The ruder hillocks of Porites are sometimes twenty feet across."†

"Each one of these compound zoophytes commenced from a single polype; bud followed bud, and so the germ grew up into the coral tree, or dome Calculating the number of polypes that are united in a single Astræa dome twelve feet in diameter, each covering a square half inch, we find it exceeding one hundred thousand; and in the Porites of the same dimensions, in which the animals are under a line in breadth, the number exceeds five and a half millions: there are, consequently, five and a half millions of mouths and stomachs to a single zoophyte, contributing together to the growth of the mass."

The train of thought awakened by these statements is essentially poetic, and has been beautifully expressed by the gifted author of the "Pelican Island." (See page 210.)

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* Dana, page 84. † Ibid., page 60.

Let us look at the coral island at a later period. On its shores are shell-fish of various kinds, sea-urchins and other marine animals, while its lagoon contains inhabitants peculiarly its own. Nor are these merely animals, such as the humble zoophytes we have been considering; there are others which make them their prey, and live upon them. Numbers of fish of the genus *Sparus* feed exclusively on the living coral. At Keeling Island there are two species of them, both of a splendid bluish-green colour; and, strange to say, one species lives invariably in the lagoon, and the other amongst the outer breakers. Whole shoals of them, we learn from Mr. Darwin, may at times be seen browsing with their strong bony jaws on the tops of the coral branches. Turtles frequent the smooth water, and a crab which grows to a great size, and which shall be mentioned hereafter, breaks open the shell of the cocoa-nut, and feasts upon the kernel.

The vegetation, too, is peculiar, from seeds which must have been transported by the waves of the sea, and accordingly "has quite the character of a refuge for the destitute."* It has been conjectured that many of those seeds, before germinating, must have travelled between 1,800 and 2,400 miles!† The ocean, which supplied to the coral workers their food and the material for their structure, thus conveys the seeds which are to cover the infant isle with verdure.

To trace further the progress of the coral island would here be out of place; and equally so would it be to speculate on the changes with regard to the Pacific and Indian Oceans that future ages may witness, when what are now but low coral reefs may become lofty mountain summits, and calcareous deposits, now silently in course of formation, may constitute a part of the mineral riches of wide-spreading and populous continents. The labours of zoophytes, humble as those here described, began in the earliest ages of animal life upon the earth, and during all its mutations have never ceased, though transferred to new theatres of action. Wherever they have been, they have left enduring monuments behind; and Science has taught us to read in part the inscription which tells of their remote antiquity. There is a fossil coral reef at the Falls of Ohio, Louisville; and Sir Charles Lyell, at the house of Dr. Clapp, compared a group of these ancient corals with a set of recent corals from the Indian seas. "No one," says he, "but a zoologist would have been able to guess which set were of modern and which of ancient origin. Yet, so old are the fossils, that they are referrible to an era antecedent to the Alleghanies, the Alps, and the Pyrences; nay, even to the time when by far the greater part of the materials composing these mountain chains were slowly elaborated beneath the ocean."‡

Here let us pause, and ponder on that Almighty Power which, ages before man was created, prepared the earth for his habitation, and stored it with countless gifts. One of these is the limestone rock, whether formed of corals, or of shells, or of particles which have lost all trace of their origin. In that inanimate mass, no less than in the blooming plant and the living animal,—

> "Man may read
> The Maker's hand, intelligence supreme,
> Unbounded power, on all his works impress'd
> In characters coeval with the sun,
> And with the sun to last."—MILTON.

* Darwin's Journal. † Idem. ‡ "Second Visit to the United States," vol. ii., p. 278.

CHAPTER VII.

Order IV.—Ascidioida.

"As soft and fair to eye
As e'er was mossy bed
Whereon the wood nymphs lie."—Southey.

If we turn to the proceedings of the police courts, we occasionally are edified with a description of some fashionably-attired individual, brought forward as Capt. de Vere, *alias* the Hon. Augustus Howard, *alias* Sir Phelim O'Neill, and are told how each additional *alias* was regarded by the worthy magistrates on the bench as "confirmation strong" of the evil intentions of the prisoner. If my present clients, zoophytes of the highest rank, were to be judged by a similar test, they would most probably be set down as very suspicious characters; for they have been spoken of, written of, and published to the world, as *Polyzoa*, alias *Bryozoa*, alias *Ascidioida*, alias *Ciliobrachiata*. Yet these titles severally express some peculiarity of structure, habit, or appearance, which has been considered worthy of being expressed by a distinct name. The terms just enumerated imply that these creatures are found living together in numbers—that they incrust other animals or bodies in the manner of moss—that they have a resemblance to those molluscous animals which are without shells, and are invested with a horny or leathery covering, such as the Ascidia—and that they have the arms covered with *cilia*, in that particular differing from any of the polypes we have yet been considering.

The use of scientific terms is rather repulsive to the young, and for that reason they shall be but sparingly employed; and when introduced the meaning shall, in all cases, be given. They cannot be passed over and altogether omitted; nor is it desirable that they should, for a knowledge of them is in many ways of importance. They often convey, in one word, a meaning which would require several distinct English words to express; and being derived in most instances from the Greek and Latin tongues, they are understood by well-educated men in every part of the world. The language of science is not English, or French, or German; it is not the dialect of any one nation, but is a language common to scientific men, no matter to what country they belong. But for this kind of universal language, it is obvious that great confusion would ensue in the terms employed by scientific men, and that discoveries made in one country would remain unknown or imperfectly understood in another. Science, however, extends her sway over all the kingdoms of the earth wherein civilized man is found, and to some extent bestows upon her subjects the community of intercourse arising from the use of a common language.

Let not my young friends, then, be frightened when they now and then meet with a "hard" word; it is not in reality half so "hard" as it looks. Let them be content to pause for a little, and understand what it means; once that is done, the difficulty is surmounted, and will never trouble them again. If they only face it manfully, success is certain. Just as in those

delightful tales of enchanted castles, defended, as we have read in our boyhood, not by giants only, but by—

"Gorgons, and Hydras, and Chimæras dire :"

if the knight lost heart, he was at once overpowered; but if he marched boldly onward, the monsters fled at his approach, and the castle was won.

Returning from this digression, it may be remarked, that although it is found convenient to speak of polypes of the present order along with other zoophytes, their many and strong points of resemblance to the ascidian molluscs had induced some of those naturalists who had given most consideration to the subject to come to the conclusion that their true place should be among the mollusca. But no trace of a nervous system had been discovered, and no change in the existing arrangement was therefore made. In fact, none has been made up to the present time; but their place is no longer a matter of uncertainty, or one resting on theoretical inference; for at the meeting of the British Association, held at Birmingham in 1849, Dr. Allman read a paper, showing the existence of a nervous system, and the distribution of the nerves in some polypes of this order. Professor Milne Edwards then remarked, that "Professor Allman's discoveries in the anatomy of the Bryozoa left no longer any doubt of the true position of these animals; that they were constructed in every respect on a true molluscan type, and must henceforth be referred to the genuine mollusca."

None of the animals of this order are found separate or naked, but are always placed within the cells of a common dwelling, or polypidom. Sometimes they incrust dead shells with a beautiful lace-work; sometimes they enamel the surface of the larger sea-weeds; and at other times, as in the example annexed (Fig. 19), they assume a plant-like form, and are known by the name of "sea-mats."* Though the entire substance is not thicker than a sheet of letter-paper, it contains rows of cells on each side. These cells differ in shape in different species: in one that is common on many parts of the coast (*Flustra truncata*) they exhibit, when magnified, the appearance represented in Fig. 20.

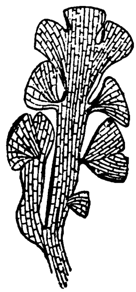
Fig. 19.

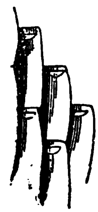
Fig. 20.

In such structures the number of cells may well be supposed to be very great. It is so, even in species that have cells on one side only, such as the *Flustra membranacea*, which forms a gauze-like incrustation on the fronds of the larger sea-weeds. The Rev. Dr. Landsborough mentions his having seen a specimen of this zoophyte five feet in length, and eight inches in breadth. And he adds, "As every little cell had been inhabited by a living polype, by counting the cells on a square inch, I calculated that this web of silvery lace had been the work and habitation of above two millions of industrious, and, we doubt not, happy inmates; so that this single colony on a submarine island was about equal in number to the population of Scotland."

It is not a little curious to consider that creatures so minute as these

* Genus *Flustra*—a word derived from the Saxon, and signifying "to weave."

should, in some points, be so highly organized, that Professor Owen, after giving structural details which would here be out of place, remarks that they "present an alimentary canal as complicated and as highly elaborated as in the bird." And perhaps it is even more curious, and far more interesting to reflect on the fact that these microscopic polypes, though fettered in their mature condition to one spot, and wholly incapable of change, enjoyed for a brief period, as ciliated gemmules, the power of locomotion—that being the means appointed for their dispersion and distribution. There is a species described by Mr. Hassall, the gemmules of which are of such a size as to be seen by the unassisted eye, and which perform their evolutions with great ease and rapidity. "They may be often seen to run along the water in a straight line for several inches, at a pace which would far outstrip the fleetest Newmarket racer—the relative sizes of the two creatures being taken into consideration. And it is not a little curious to observe that, no matter how many ova may be moving about in the same space, still they never come in contact, appearing to avoid each other as carefully as though they were possessed of eyes."

Some ascidian zoophytes are found in fresh water, and exhibit a beautiful horse-shoe crescent of tentacula.

I have but another remark to make; it is that some of these ascidian polypes are possessed of luminosity, in that respect resembling some of those previously noticed. Of one such species (bearing the name *Membranipora stellata*), Dr. Landsborough happily remarks, that on being bent or shaken, it "became doubly entitled to the name of stellated; for every polype in its cell lighted up a very brilliant little star, and for a short time the polypidom became like an illuminated city."

Fig. 21.

As many of these animals, and others to be named hereafter, live "full fathoms five" under the sea, and must be sought for occasionally at depths of twenty or thirty fathoms, or even more, it may naturally be asked, By what means are they to be reached? The instrument most effective for this purpose is cheap, simple, and easily managed. It is known as the Naturalist's Dredge, or as Ball's Dredge, so called from Dr. Ball, of Dublin, the gentleman by whom it has been brought to its present state of portability and usefulness.

The upper part consists of an iron rim of four sides, to which a bag of fine network or open canvas is attached (Fig. 21). The two longest sides are twelve inches each in length, the shorter, or connecting sides, three inches. The longer sides are thick below, and "bevelled" away above. Attached to the shorter sides are two arms, which are united together above by a screw passing through a ring, and can be separated at pleasure. These arms are attached by pivots to the side, so that they turn with ease, and thus adapt themselves to the varying position of the dredger, the greater or less length of his rope,

and the quicker or slower movement of the boat. Possessing this simple means of adjustment, the dredge, attached by a rope, which the dredger holds in his hand, is slowly dragged along the bottom, and marine productions of various kinds collected in its net or bag.

One or two small wire sieves of different degrees of fineness are convenient for receiving the contents of the dredge when pulled up, and giving facilities for washing them from mud and sand, and separating the more delicate specimens from those by which they might be injured. I have found, also, a small basket, with divisions, such as those used by wine-merchants for keeping bottles from coming into contact, very useful and convenient for holding in safety a few open-mouthed glass jars, to which living specimens might be at once transferred, and kept alive in sea-water for examination. One single "haul" of the dredge will sometimes furnish occupation for successive days.

And, as I am speaking of implements, I may mention another, which is even more portable, and more easily managed—a towing-net. A hoop of stout brass wire, about equal in diameter to the crown of a man's hat, can be procured almost anywhere. A bag of open canvas, or any similar material, is sewed round this hoop, and three strings attached, as shown in the annexed sketch (Fig. 22). They are joined to a cord, which may either be held in the hand or tied round any convenient part of the boat. On a fine summer day such a net can be used without toil or trouble; its contents can be transferred to the glass jars filled with sea-water; and endless is the variety of lovely animated forms that will thus present themselves to the eye of the observer.

Fig. 22.

This simple, inexpensive, and easily-managed apparatus I would venture to recommend to all who spend a portion of the summer months at the sea-side. It will open to them a new source of amusement, and tempt them onwards in the investigation of nature. I have known a lady to convert an old veil into a most effective towing-net, and have seen her chimney-piece decorated with living blossoms not less beautiful than those of the parterre. There are some of those sea animals so transparent that they appear like crystals endued with life, and moulded into beauty; and I trust a time is now coming when the knowledge of them will not be confined to the man of science, but extended to all who, with pure eyes and simple hearts, look abroad on the fair face of creation; and, in the rippling wave of the summer sea, no less than in the daisy-spangled lawn, seek out the marvels with which they are replete, and feel, while doing so, the deep significance of the words, "The sea is HIS, and HE made it, and HIS hands prepared the dry land."

CHAPTER VIII.

CLASS IV.—RADIARIA, OR RAYED ANIMALS.

THE figure of a Star-fish was introduced at page 278 as an example of what is meant by a rayed or radiated animal. We have now reached the class to

which the Star-fish belongs, and as the rayed appearance here attains its highest degree of development, to this group the title *Radiaria* is given. Here are found those creatures which may be regarded as the representations or types of the Radiate animals, such as the Star-fish, with its rays or arms round a centre; and the Sea-urchin, with its rows of little knobs and spines diverging from a central spot. There are, however, other animals which are not furnished with a hard, leathery, or prickly covering; but, on the contrary, are soft and jelly-like, such as those which are known round the coast by the names of Jelly-fish, Sea-jellies, or Sea-blubber. In them, however, there are rays proceeding from the centre to the circumference, like the radii of a circle, so that they also belong to this division. The difference in structure and covering points out, however, a very natural division of the class; just as if it were arranged that two corps intended to live under very different circumstances should each bear its distinctive uniform, adapted to the exigencies of the service, and the safety and comfort of its members. The spine-covered *Radiaria* form a group whose duties are performed about the shores, or at moderate distances from land, and at fathomable depths. The gelatinous *Radiaria*, on the contrary, have as their dwelling

> "The sea, the sea, the open sea."

Shakespeare tells us of

> "A mermaid on a dolphin's back,
> Uttering such dulcet and harmonious breath,
> That the rude sea grew civil at her song;
> And certain stars shot madly from their spheres,
> To hear the sea-maid's music."

I will not venture to affirm that these stars were changed into Sea-jellies and Star-fishes, and that this is the reason they still retain a certain degree of resemblance to their original form. But I may assert that the common names, both in our own and in foreign dialects, evince a popular recognition of a real or supposed likeness. Such an idea must have been in the mind of the poet Montgomery when he penned the lines—

> "The firmament
> Was throng'd with constellations, and the sea
> Strewn with their images."

Let us, however, now regard them, not with the eye of the poet, but with that of the naturalist.

ORDER ACALEPHÆ, OR SEA-NETTLES.

> "Far as the breeze can bear, the billows foam,
> Survey our empire, and behold our home!
> These are our realms."—BYRON.

I was staying with my family at the sea-side during the summer months, and was returning home one evening, when, as I approached the door, I heard loud and violent crying. Quickening my steps, I found the cries proceeded from one of my boys, a little fellow about eight years old. He was sitting in the hall more than half undressed, and roaring with pain. I found he had been bathing, and had been severely stung by a jelly-fish. These creatures have long been celebrated for this stinging power. It was well

known to the old Greek naturalists, who gave to the order the scientific name *Acalephæ*, signifying a nettle, a term which they still retain as their distinctive appellation.

But although some species might, because of this power, be justly raised "to that bad eminence," the name is not restricted to them; and hence the innocent are confounded with the guilty. Not more than three or four species of those known on the British coasts do in reality sting; all the rest are harmless.

The appearance of the large tawny-coloured species, when seen in the water, on a fine summer or autumn day, is extremely beautiful, as it gracefully moves by the contraction and expansion of the outer margin of the "umbrella," or disc, exhibits its fringed margins, and rises to the surface, or sinks at pleasure beneath. Earlier in the year we may find our boat surrounded by others marked with purple circles, and so numerous are these jelly-fishes that on some occasions its progress is even retarded by the resistance they offer. Our walks along the shore furnish us with examples of many hundreds of both kinds stranded on the beach, and known by the classic appellation of Medusæ.

It is curious to examine one of these great pads of jelly, and find how little solid matter it contains. One tested by Professor Owen weighed two pounds at the time of its removal from the sea; but when the watery parts were drained away, and the remainder dried, there remained but a thin membrane not exceeding thirty grains in weight. This remarkable peculiarity is so little known, that I shall extract from Patterson's *Zoology for Schools* the following illustrative anecdote :—"An eminent zoologist, now a professor in one of the English universities, had been delivering some lectures in a seaport town in Scotland, in the course of which he had adverted to some of the most remarkable points in the economy of the Acalephæ. After the lecture, a farmer who had been present came forward and inquired if he had understood him correctly, as having stated that the Medusæ contained so little of solid material that they might be regarded as little else than a mass of animated sea-water? And on being answered in the affirmative, he remarked that it would have saved him many a pound had he known that sooner, for he had been in the habit of employing his men and horses in carting away large quantities of jelly-fish from the shore, and using them as manure on his farm, and he now believed they could have been of little more real use than an equal weight of sea-water. Assuming that so much as one ton weight of Medusæ recently thrown on the beach had been carted away in one load, it will be found that, according to the experiments of Professor Owen, the entire quantity of solid material would be only about four pounds of avoirdupois weight, an amount of solid material which, if compressed, the farmer might, with ease, have carried home in one of his coat pockets!"

As the Medusa moves gracefully through the water, we might suppose that the entire of the disc, or "umbrella," contracted and expanded. But this is not the case; it is the part round the margin that alone possesses this contractible power. The lower surface of the body has a fine network of vessels, wherein the circulating fluids are exposed to the vivifying influence of the oxygen of the water. Each movement becomes, therefore, an act of respiration: by the same impulse it both breathes and moves. This beautiful and economic arrangement has suggested the application of a term by which this

peculiarity is indicated. The tribe has been termed Pulmograde, from two Latin words, *pulmo*, a lung, and *gradior*, I advance. Analogous terms, some of which will be mentioned in the next chapter, have been suggested by peculiarities in the mode of locomotion observable in other tribes.

The sexes in the Medusæ are distinct. From the eggs, while yet within the ovaries of the mother, the young are developed, and pass into pouches observable on the lower surface of the body. Each of these four pouches is a nursery, where, secure from harm, the first stages of helpless infancy are passed; here the young become covered with the minute, hair-like bodies called *cilia*, and are thus enabled, when they forsake the parent, to swim about in the water. We read with interest and wonder of the marsupial pouch of the kangaroo, where the immature young is nourished: here is an analogous contrivance, belonging to an animal of humble rank, living by thousands on our own shores.

Let us now pursue the progress of the young Medusa. After swimming about for some time under the form shown at Fig. 23, it fastens itself to some fixed object (Fig. 24), and four arms are gradually developed, which are succeeded by four more (Fig. 25), so that in ten days from the time it left the parent receptacle it is furnished with eight arms, which are busily employed in the capture of food. At first it swam about in the manner of a polygastric animalcule; now it catches its prey, moored like one of the Rotifera, and employing its arms like one of the hydraform polypes. Sometimes it sends out what in a strawberry plant would be termed a runner—sometimes buds grow from its side (Fig. 26). When the body has attained its full length, wrinkles are formed round the body (Fig. 27); these increase in depth, until the segments of the body seem almost detached, or resembling a pile of cups (Fig. 28).

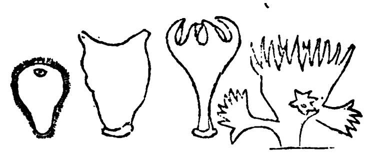

Fig. 23. Fig. 24. Fig 25. Fig. 26.

Finally, these separate; each, after certain intermediate changes, puts on the form shown in Fig. 29, and becomes converted into the common Medusa of our shores, *Medusa aurita*, with the four purplish heart-shaped markings.

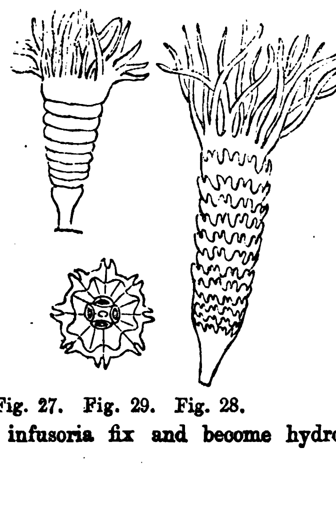

Fig. 27. Fig. 29. Fig. 28.

In the latter months of summer the ova are mature; the young become fixed in the autumn; pass the winter in the polype condition; appear again in the immature state in spring, and increase to their full size as the summer advances. The series of changes is truly wonderful; so much so, that if it were not given on the testimony of several distinct observers of high character, its accuracy might be doubted. It may be summed up thus. —1. The Medusa produces eggs. 2. The eggs produce Infusoria. 3. The infusoria fix and become hydroid

Polypes. 4. The hydroid polypes produce Medusæ. For fuller information the reader is referred to one of the publications of the Ray Society, Steenstrup, *On the Alternation of Generations.*

The Medusæ we have been considering are of large size. At certain distances round their margins they have eye-like bodies, which are regarded as light-perceiving organs of a rudimentary kind; and these are protected by hoods, or coverings. There are, however, numerous species small in size, more simple in structure, and with the eyes unprotected. I would wish to introduce these animals to my readers by extracting a few passages from the highly interesting and valuable monograph of Professor Edward Forbes on the "Naked-eyed Medusæ," another of the Ray Society's volumes.

The accompanying figures will show that among the naked-eyed Medusæ there exists considerable difference of form. Fig. 30 is an enlarged representation of *Modeeria formosa;* but wanting, of course, the bright crimson tints that decorate the original. Professor Forbes states that it was taken by him and his friend, Mr. McAndrew, off Mull, in the Hebrides, and thus introduces it to his readers:—"The largest objects are not always the most beautiful. Little diamonds may sparkle brighter than the monster gems of a regal crown. There is not a Medusa in all the ocean which can match, for beauty, with the minute creature now before us, though its smallness is such that a split pea would overtop it. Yet, small though it be, it has shape, colour, and substance so disposed, that as yet no explorer of the sea has met with another like it. It is gorgeous enough to be the diadem of the smallest of sea-fairies, and sufficiently graceful to be the night-cap of the tiniest and prettiest of mermaidens."

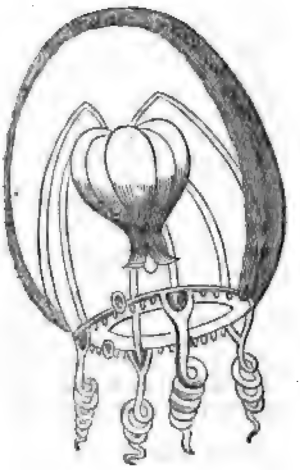

Fig. 30.

The next is a figure (Fig. 31), of *Thaumantias pilosella*, which sometimes attains the diameter of two inches. Of this genus Professor Forbes describes no less than seventeen British species. They swarm in countless myriads in our bays and harbours, and are one of the most usual causes of the beautiful phenomenon—the phosphorescence of the sea.

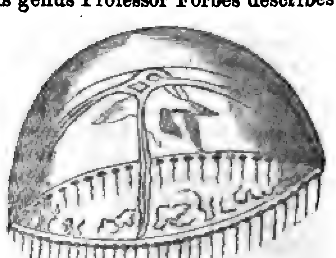

Fig. 31.

The classic reader may perhaps take a greater interest in the naked-eyed Medusæ, if he be told that "several of them are now known to multiply their kind by germination, little ones springing out almost ready made from the substance of their parents, as Minerva budded on the creative brain of Jupiter. This mode of propagation by gemmation was long supposed among Radiata to be an especial privilege and distinction

the true zoophyte; but the march of discovery and the revolutions of science do away with such artificial distinctions, though the recognition of them in their time gave no small impulse to the onward progress which was eventually to destroy them."

The development of the young becomes peculiarly interesting when contrasted with what has been stated of the larger Medusæ; and curious enough, they spring from different parts, such as the ovaries, the stomach, which forms a part of the peduncle hanging from the lower surface of the umbrella, and even from the bulbous base of each of the tentacula which fringe the margin. After describing in detail this latter mode, as observed by him in *Sarsia prolifera*, Professor Forbes remarks:—"What strange and wondrous changes! Fancy an elephant with a number of little elephants sprouting from his shoulders and thighs, bunches of tusked monsters hanging epaulette-fashion from his flanks in every stage of advancement! Here a young pachyderm, almost amorphous—there one more advanced, but all ears and eyes; on the right shoulder a youthful Chuny, with head, trunk, toes, no legs, and a shapeless body; on the left an infant, better grown, struggling to get away, but his tail not sufficiently organized as yet to permit of liberty and free action. The comparison seems grotesque and absurd, but it really expresses what we have been describing as actually occurring among our naked-eyed Medusæ."

Well may we doubt if the line of separation between the Zoophytes and the Medusæ is a legitimate boundary, and can be rationally maintained. Sir John Dalzell, in his *Rare and Remarkable Animals of Scotland*, mentions that from an hydroid zoophyte, "a colony, computed at 130 individuals, of the *Medusa ocilia*, was produced in four or five days; and there are grounds for assuming that successive colonies come from the same specimen of the zoophyte." If future research should prove that our present ideas respecting the classification of these animals is incorrect, we must not hesitate to throw them aside. "Free and unprejudiced spirits will neither antiquate truth for the oldness of the notion, nor slight her for looking young, or bearing the face of novelty."*

The use of the little towing-net may perhaps enable some of my readers to capture naked-eyed Medusæ for examination in the course of some summer's ramble. They will then observe that the eyes of different species are of very different colours—purple, orange, and yellow; and with regard to number, Argus, the hundred-eyed, must yield to one at least of "those dark-eyed beauties," for it can boast of twice as many. Or if you should desire to witness a tragic scene on a small scale, you may become a spectator of the doings of another species (*Steenstrupia rubra*), which is only about the one-eighth of an inch in length. "It is," says Forbes,† "very active and tenacious of life; before dying assuming all manner of strange shapes, doubling itself up, and turning its organs inside out in a terrific manner, giving up the ghost with convulsions as fearful as those of a popular actor in the death scene of a tragedy." Or should you desire to witness the union of qualities that are rarely combined in the same individual, endeavour to secure some specimens of *Sarsia tubulosa*, a species that at times is taken rather abundantly on some parts of the coast. "Being kept," says Professor E. Forbes, "in a jar of salt water with small crustacea, they devoured

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* *Henry More*, born 1614, died 1687, one of the earliest Fellows of the Royal Society.
† *Thaumantias melanops*, Forbes, p. 45.

these animals, so much more highly organized than themselves, voraciously, apparently enjoying the destruction of the unfortunate members of the upper classes with a truly democratic relish. One of them even attacked and commenced the swallowing of a *Lizzia octopunctata*, quite as good a Medusa as itself. An animal which can pout out its mouth twice the length of its body, and stretch its stomach to corresponding dimensions, must indeed be 'a triton among the minnows,' and a very terrific one too. Yet is this ferocious creature one of the most delicate and graceful of the inhabitants of the ocean—a very model of tenderness and elegance."

CHAPTER IX.

ORDER VI.—ACALEPHÆ.—CILIOGRADES.

"O happy living things! no tongue
Their beauty might declare."—COLERIDGE.

IF on a fine summer's day your boat should be gliding gently along—or, better still, if your boat should be anchored where the tide is flowing, you will at times see a large jelly-fish floating on the surface, and borne unresistingly along by the current. Under such circumstances it recalls to the imaginative mind the words of the poet:—

"Still must I on; for I am as a weed
Flung from the rock, on ocean's foam to sail,
Where'er the surge may sweep—the tempest's breath prevail."

And we might fancy that the very individual we looked upon, or others of the same species, might thus be conveyed to any latitude. But we should be wrong; these children of the ocean have their appointed range. The laws of geographical distribution confine them within certain limits, and they but rarely venture beyond the boundary. It is this circumstance that invests with interest the advent to our shores of the Physalia, or Portuguese man-of-war; and makes a fleet of the little Velella, with their snowy sail-like crests, be regarded with the same mixed feeling of admiration and wonder that is inspired by the arrival of some bright-plumaged bird from other lands. The Physalia, the Velella, and others belonging to the order *Acalephæ*, might here be dwelt upon, but that I prefer occupying the brief space at my disposal with a description of creatures that may be sought for, and not in vain, on many parts of our coast during the summer months.

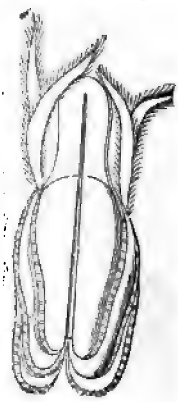

Fig. 32.

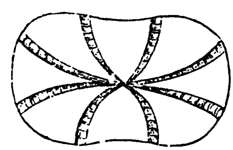

Fig. 33.

Instead of moving by the contraction and expansion of the marginal disc, like the jelly-fishes, they move by means of *cilia*, and hence bear the appellation of "Ciliogrades." Some are not uncommonly spoken of by the name Beroë,

which belongs to one of the genera, and, like the term Medusa, is of classic origin, as it was applied to one of the fabled sea-nymphs.

Two species happen to have fallen especially under my notice, and a description of their habits and peculiarities may serve to illustrate some of the most interesting points in the economy of their respective families.

If the little towing-net (Fig. 22, p. 303) be gently drawn after a boat, in fine summer weather, among the creatures taken in it may be some of the shape and size shown in the preceding page (Fig. 32).* They are transparent, gelatinous, and so very fragile that some little skill is necessary to transfer them safely from the towing-net to the glass vessels of sea-water in which they should be kept. But once there, the form of the body is striking, and its movements peculiar, being caused by the action of eight bands of cilia, extending over two-thirds of the longer diameter of the body. Their position as regards each other, and their arrangement on the oval body of the animal, will be understood by a reference to Fig. 33, which represents the body as seen from beneath. There is, however, nothing about them which will arrest the attention so much as four ear-shaped appendages, or tentacula. These are fringed with beautifully fine cilia, and are ever changing in form. They may be seen pointed, erect, and hollowed longitudinally, like the ears of a horse, or somewhat funnel-shaped, and occasionally either flattened or concave, with the extremity rounded. At times their position is horizontal; at others they hang loosely down, like the ears of a lap-dog, or are curved like the petals of the martagon lily.

These tentacula issue from four circular orifices. Round each of these apertures is a whitish cord-like body, fringed with cilia. When the body, owing to its great delicacy, is broken up by the tossing of tempestuous waves, or from other causes, these ciliated rings retain for many hours the full play of their cilia, and thus propelled, move about with ceaseless activity. The first evening I thus saw one of them, I fancied I had caught a nondescript, and felt rather disappointed when a little further examination showed what it really was.

Fig. 34.

In the side view of the animal (Fig. 33), the mouth, which is at the upper part of the body, could not be shown. Adjoining to it are two prominent lobes, which, however, differ very much at different times as to their form and extent.

Another species, which in many localities is much more abundant, is most commonly about the size of a boy's marble, and shaped like an apple, whence it has obtained its specific name —*pomiformis*, or apple-shaped (Fig. 34). It is of much firmer consistence than the other, and more vigorous in its movements. These are accomplished by means of eight bands of cilia, which, by their action, remind the

* This is a lateral view. For many details not here given, *vide* Trans. R. I. Academy, vol. xix., Papers on *Cydippe pomiformis* and *Bolina Hibernica*.

beholder of the paddle-wheels of a steamboat. But how poor is man's mechanism compared with that which they display! Each of the eight bands of cilia can in a moment be stopped or brought into action, and the rapidity of the movement regulated at the pleasure of the animal. Aqueous currents may be seen, by means of the microscope, ascending and descending along the bases of these bands of cilia, forming the propelling power. The Fig. 35 is a magnified view of a portion of one of these bands. To appreciate them fully, they must be seen in motion, when at every stroke in the water they give rise to a beautiful iridescence, and the creature swims surrounded by a brilliant halo of rainbow tints, born and dying at each fresh impulse.


Fig. 35.

This species, *Cydippe pomiformis*, usually swims with the mouth upwards, though at times it performs such gambols and somersaults, that, like the brewer's horse in the song, it turns the head where the tail should be. The food appears to consist of small crustacea, which it bolts without ceremony. In most cases when food is swallowed we have no longer cognizance of it, and can speak of it only from its effects. But here, owing to the transparency of the animal, brown or greenish crustacea, recently swallowed and still living and moving, may be distinctly seen within the stomach, until, as the process of digestion goes on, they gradually disappear.

If, however, the Beroës feed upon small crustacea, they in turn furnish a supply of food to creatures more powerful than themselves. I have seen two of them swallowed by an Actinia, or Sea-anemone, in the course of twenty minutes. Next morning portions of the bands of cilia and more solid parts of the Beroës were observed rolled together, and adhering, with some darkish-coloured pellets, to the filaments of the Actinia, whence, after some time, they were thrown off. On another occasion one of the small naked-eyed Medusæ closed its arms on a Beroë, but I am shocked to say that the embrace was not a loving one, for the Medusa had cut "a huge half-moon, a monstrous cantle, out" of the body of its unfortunate victim. But let not my fair readers sorrow too deeply at such a catastrophe, for the Beroë seemed quite unconscious of its loss, and swam about as merrily as ever.

On each side of the body is a tubular cavity, from which a long filament can be projected. These filaments, or *tentacula*, are sometimes so much as four or five inches in length, and are furnished along one side with smaller filaments, perhaps half an inch in length, and of a delicate pinkish colour. There are sometimes so many as forty or fifty of these on one *tentaculum*: when coiled up they appear like beads, and most usually some are in this state, and others waving freely about. In this respect, however, they are incessantly varying; and the *tentacula*, to which they are attached, are at the same time continually assuming new aspects, being retracted either separately or together, and thrown out in the same diversified manner. It is scarcely possible to convey, by any description, an idea of the beauty and diversity of their forms. They seem endued with exquisite sensibility, which, however, is not always equally delicate. At times the slightest touch will cause a *tentaculum* to be drawn back into its tube with a sudden

jerk; at other times it is apparently unfelt. What is the use of these singular organs? is a question more easily asked than answered. It has been supposed that they are used in the capture of food; but as yet this is only a supposition. Though I have had hundreds of specimens in my possession in a living state, and watched them narrowly, I never had the good fortune to see the *tentacula* so employed. They were sometimes extended to the sides or bottom of the glass vessels, and formed fixed points of support, so that the Cydippe, like a fairy bark, seemed to ride at anchor, moored by cables as complex, yet as delicate, as any of those that the attendants on Titania ever fabricated.

Lamarck observes—"Les Beroës sont très-phosphoriques; ils brillent pendant la nuit, comme autant de lumières suspendues dans les eaux; et leur clarté est d'autant plus vive que leurs mouvements sont plus rapides." They do not appear, however, to emit this light at all times and seasons. I have shaken the vessel in which the Cydippes were confined, and failed to produce any phosphorescence, and have even plunged the animal into fresh water with no better result. In general, however, the light is freely given out when, by any means, a slight irritation is applied. On one occasion I had twenty or thirty of the larger species in an opaque vessel, in a dark cellar. On agitating the water the whole contents of the vessel became lighted up so completely as to render all the adjacent objects visible for a moment. On touching them, light was invariably given out from beneath the bands with increased brilliancy, every portion of the cilia being distinctly exhibited, with a splendid greenish lustre, as beautiful as it was evanescent. It was impossible to behold these bodies of innocuous fire, floating amid the brightness which they themselves diffused, and not feel that to convey an adequate idea of their beauty would be a task more fitted for the imagery of the poet than the language of the naturalist.

If an incision be made in the body of a Beroë when dead, and the watery particles allowed gradually to evaporate, the bands of cilia and the tentacula will appear as if painted in a confused manner on the surface whereon the body has been placed, and when perfectly dry can be removed by a touch, as completely as if they had never formed a portion of animated existence.

CHAPTER X.

ORDER VIII.—ECHINODERMATA.—STAR-FISHES.

"Come unto these yellow sands,
And then take hands."—SHAKESPEARE.

A FAIRY TALE.

ONCE upon a time there grew beneath the waters of the sea a delicate-looking little plant. It had a spreading base, and a stem surmounted by many branches; yet so tiny were its dimensions, that the piece of gold which mortals call a "sovereign" would be sufficient to cover half a dozen such miniature trees. There it grew, surrounded by the strange and varied forms

that decked the ocean bed, and visited by divers creatures that crept or swam at pleasure. Here the noise of the tempest never penetrated, and the sea at that region of depth was at all seasons calm as a sleeping infant. Yet the little tree was not content. It longed to see those wonders of which it had only heard. It wished to rise to the surface, and feel the rippling breeze as it passed along, and to know from its own experience what was meant by "tossing billows." It had heard from a communicative Beroë of the glories of a summer sky; and a diminutive jelly-fish had told of the starry splendour of an autumn night. A star-fish had given origin to a rumour that there was a limit to the waters of the ocean; and a crab, who had been a great traveller, asserted that he had walked upon the place where the sea ended, and what he called "land" began; but this was set down on all hands as a traveller's story. The discontent of the little tree increased; and we all know that this is a feeling which "grows by what it feeds on." It sought out information about its predecessors, and the collateral branches of its family; but what it learned rather increased its dejection, for it discovered that some ancient members of the family had been giants, compared with its own diminutive proportions. This went on for some time, until one of those beneficent sea-nymphs, that had not then forsaken the waters of our globe, asked it so kindly what were its troubles, that the little tree made a frank and full confession of them all. "I cannot," said the compassionate nymph, "cause your root to loosen, and bid you and your posterity be free; neither can I restore to you the stature that other members of your race enjoyed in an earlier period of this earth's history; but what lies within the compass of my power shall be done. I shall remove from your stem the spreading head with all its arms uninjured. I shall endow it with new life, and give it powers of motion, so that it may rise to meet the upper air, swim where it listeth, and even visit the boundary of the sea, though perilous it is to do so. I give to you power of growth, that your arms may increase to fifty times their present size. These gifts shall be continued to your offspring; but each of them must, like yourself, pass the early stages of its life fixed to one spot, and present the same tree-like aspect that you yourself exhibit." The nymph smote with her wand the upper part of the stem; it broke off; ten boughs, suddenly gifted with power and flexibility, became converted into arms; the head of the little tree changed into a swimming animal, and went on its way rejoicing. Its progeny, to this day, assume at first the plant-like appearance of their parents, and at a certain state of maturity are changed, like it, into free and independent creatures.

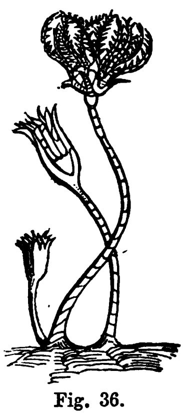

Fig. 36.

Some Fadladeen of criticism may, perhaps, exclaim, "What nonsense is all this! Why should the pages of the *Home Tutor* be occupied with a nursery tale?" Pardon, most learned critic; I have, under the guise of a fairy tale, been telling some of the sober facts of science.

The foregoing figure (Fig 36) is the little tree in its young state. You may count, if you please, its ten spreading arms; or, to speak more correctly, five

arms that become forked near the base, and appear as ten. The other figure (Fig 37) is the animal in its mature condition, at which time it is known to naturalists as the "Rosy Feather Star" (*Comatula rosacea*), a creature inhabiting our own seas, and which, perhaps, some of my readers may procure during their visits to the sea-side.

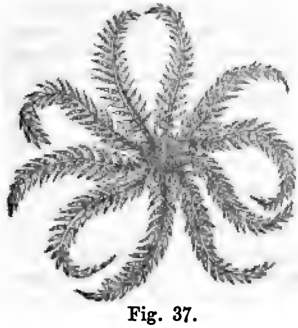

Fig. 37.

Not only is my tale true as regards the changes which the present race undergoes, but true also as to the dimensions of those that lived in remoter periods of the world.

They lived and died rooted to one spot; and large tracts of land are composed wholly of their remains. The beautiful appearance their skeletons present has caused them to be popularly known as "Stone-lilies." The naturalist adopts the idea, and entitles them "Crinoid," that is to say, "Lily-like" star-fishes. All possessing a similar structure, whether fixed, like those of Old Time, on our own coasts, and some tropical species yet living, or fast moored at one period, and free at another, like those now found in European seas, are included in this family.

The arms are composed of perforated calcareous joints, which, when found as fossils, and in detached fragments, are known by the common English name of "Wheel-stones;" and in some parts of the north of England by that of "St. Cuthbert's Beads."

The Star-fishes belonging to the next family have a roundish central body, and five long tapering arms, each of which bears some resemblance to the tail of a serpent. From this circumstance the name *Ophiuridæ* has been applied to the group; the word *ophiura* meaning a serpent's tail. These star-fishes differ exceedingly in size; and some of them are so small that if the creature would be so obliging as to pull in his arms when you desired it, a silver fourpence would cover the body and the five tapering arms. One evening towards sunset I was strolling with some children on the beach, prying into the little rock-pools as we went along, when suddenly I was desired to look at some curious little things that were waving amid the common coralline of the pools. I did so, and found they were the arms of a small-sized star-fish (*Ophiocoma neglecta*). Many of my readers may not have the opportunity of seeking for them in such situations; yet, by enlisting the aid of their cook, they may now and then procure species of great rarity. One of these, a minute species, with long arms, and a body only one-eighth of an inch in diameter (*Ophiocoma punctata*), is thus mentioned by Professor Forbes in his *History of British Star-fishes*:—

"The stomachs of fishes are often zoological treasuries. The haddock is a great conchologist. In his travels through the country of the mermaids he picks up many curiosities in the shell way. Not a few rare species have been discovered by him; and the ungrateful zoologist too frequently describes novelties, without an allusion to the original discoverer. As haddocks

are not in the habit of writing pamphlets or papers, the fraud remains undiscovered, greatly to the detriment of science; for had the describer stated to whom he was indebted for his specimens, we could form some idea of its habitat and history, whether littoral or deep sea—very important points in the economy of Mollusca—important not only to the malacologist, but also to the geologist. Like the haddock, the cod also is a great naturalist; and he, too, carries his devotion to our dear science so far as occasionally to die for its sake, with a new species in his stomach, probably with a view to its being described and figured by some competent authority. The cod is not so much devoted to the Mollusca as to the Echinodermata; and doubtless his knowledge of the Ophiuræ exceeds that of any biped. He has a great taste for that tribe.

But although some star-fishes may be got in rock-pools, and some may be found "quietly inurned" within the stomach of fishes, the great field on which they are to be sought is the ocean bed. By means of the dredge, figured at page 302, you may be able to examine them in their living state. One of the most abundant species in certain localities is that represented in Fig. 38. It is the common Brittle Star (*Ophiocoma rosula*), and well deserves its English name. When your dredge has been emptied, you see a mass of snaky-looking arms twining about, and even while you look some of them separate from the rest. Struck at so strange a sight, you lift up one for closer examination: in a moment all the arms are flung off, and the central disc alone remains in your hand. The only way to prevent this disruption is to have a vessel of fresh water on board, and throw into it such specimens as you wish to preserve in their full integrity. They die instantaneously: a momentary *dip* into boiling water, and exposure to a good fire, or a brisk current of air, will preserve them sufficiently to enable you to pack them up, and convey them in safety homeward.

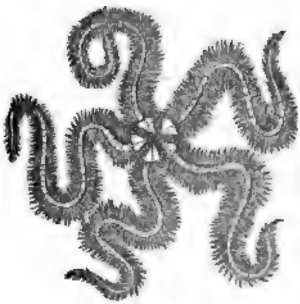

Fig. 38.

The common Brittle Star is really a pretty and a curious object. You can scarcely find two that are quite alike; they differ in size, in the spinousness of their arms, and in the variety of bright colours, blue, orange, yellow, pink, and red, that they exhibit. Their distribution seems to be greatly influenced by the nature of the sea-bottom. Your dredge at one "haul" may bring up a score or two, all of this species. In another half hour, when you have changed your situation, not one of them is to be found; but others, destitute of the spiny investment, supply their place.

Passing on now to a third family (*Asteriadæ*), we have what are regarded as the true star-fishes (Fig. 39). The five arms here are not mere appendages to the central disc, but each of them contains within itself a part of the digestive system, diverging from the stomach, which is in the central portion of the body. Deep grooves, or avenues, run along the lower surface of each ray, and these are pierced by numerous apertures, through which hundreds of suckers can be extended, and perform the functions both of feet and of hands, for they serve as means for locomotion, and instruments for securing their prey.

Sars, a Norwegian naturalist, has made us acquainted with some interesting facts regarding the production of the young of one species, and the changes which they undergo. The annexed figure (Fig. 39) is a copy of one by him, representing the lower surface of the body of the "Eyed Cribella," as it is called by English naturalists. The eye is situated at the extremity of each ray, and is protected from injury by a ring of spines. The eggs, after passing from the ovary, do not escape at once into the sea, but the arms which are exhibited in the figure close upon them, and thus retain them in a kind of artificial pouch. So long as the mother keeps them in this way, she may be said to convert a portion of her body for the time being into a receptacle analogous to the marsupial pouch of the kangaroo or opossum. During all that time she is voluntarily deprived of any means of obtaining nourishment, and is compelled to continue with the segments of her body in a very contracted state. This she has been observed to do for *eleven* successive days—a striking and remarkable example of maternal care in a creature of a very humble grade of organization.

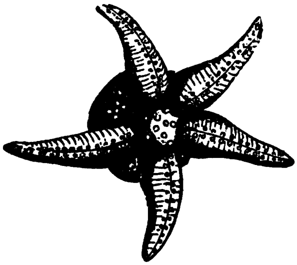

Fig. 39.

The young, when liberated, swim freely about, undergo a series of transformations which are fully described and figured, and at the end of a month assume the appearance of radiate animals. Of the precise changes in other species we are at present uninformed. It is possible that some reader of the *Home Tutor* may yet be the first to give the information of which we are at present destitute, and thus contribute his quota to the stock of scientific knowledge.

CHAPTER XI.

ORDER ECHINODERMATA.

"In hollows of the tide-worn reef,
Left at low water, glistening in the sun,
Pellucid pools, and rocks in miniature."—MONTGOMERY.

THE common Cross-fish (*Uraster rubens*) is plentiful round our shores, and is most generally from eight to twelve inches in diameter. I have seen one, measuring nearly twelve inches across, taken out of the stomach of a cod-fish, though by what arts of persuasion the cod had induced its victim to fold its arms into a convenient compass for being gulped down was beyond my comprehension. It is sometimes found with six rays, and sometimes with only four; and occasionally four rays of the proper size, and one in course of formation; for if an arm be amputated by any casualty, another grows in its stead. It is a common opinion among fishermen, when they see one of these animals minus a ray, that the loss was sustained in an attempt to take a gaping oyster out of its shell, that the valves of the shell

had closed on the intruding arm, and that the Cross-fish, finding too late he had "caught a Tartar," was glad even with the loss of an arm to effect his escape. There is no doubt the Cross-fish is injurious to oyster-beds, but in a different way. He is said to pout out the lobes of his stomach, so as to convert them into a proboscis, and by means of this instrument to apply to the oyster a poisonous or benumbing secretion, after which he can devour the mollusc at pleasure.

When the Cross-fish is brought up in the dredge, and thrown on the deck or the rowing-bench of a boat, he appears perfectly helpless. But drop him into a bucket of sea-water, and his aspect is soon changed. Long, slender, white, worm-like bodies are extended from the under surface of each arm; as their number increases, you would almost fancy you were looking at a colony of polypes, rather than a remarkable series of instruments, which serve not only for progression, but also for seizing and overpowering a prey. Each is, in fact, a sucker, and takes a firm hold of any surface to which it is applied, so that what was before a helpless-looking creature is soon observed marching with an easy gliding motion across the bottom of the bucket, or even ascending its perpendicular sides.

There is, however, one species of this tribe that resembles the Brittle Stars in its power of breaking itself up. This is described so humorously by Professor E. Forbes, that I use his own words, and refer such of my readers as are of opinion "it is good to be merry and wise" to his *History of British Star-fishes.*

"It is the wonderful power which the *Luidia* possesses, not merely of casting away its arms entire, but of breaking them voluntarily into little pieces with great rapidity, which approximates it to the *Ophiuræ*. This faculty renders the preservation of a perfect specimen a very difficult matter. The first time I ever took one of these creatures I succeeded in getting it into the boat entire. Never having seen one before, and quite unconscious of its suicidal powers, I spread it out on a rowing-bench, the better to admire its form and colours. On attempting to remove it for preservation, to my horror and disappointment I found only an assemblage of rejected members. My conservative endeavours were all neutralized by its destructive exertions, and it is now badly represented in my cabinet by an armless disc and a discless arm. Next time I went to dredge on the same spot, determined not to be cheated out of a specimen in such a way a second time, I brought with me a bucket of cold fresh water, to which article star-fishes have a great antipathy. As I expected, a *Luidia* came up in the dredge—a most gorgeous specimen. As it does not generally break up before it is raised above the surface of the sea, cautiously and anxiously I sank my bucket to a level with the dredge's mouth, and proceeded in the most gentle manner to introduce *Luidia* to the purer element. Whether the cold air was too much for him, or the sight of the bucket too terrific, I know not, but in a moment he proceeded to dissolve his corporation, and at every mesh of the dredge his fragments were seen escaping. In despair I grasped at the largest, and brought up the extremity of an arm, with its terminating eye, the spinous eyelid of which opened and closed with something exceedingly like a wink of derision."

We now come to the Sea-urchins, a family in which the rayed appearance is different from what it is in the star-fishes. The form is somewhat globular, occasionally depressed, and covered with spines, which are different in different groups. Its spiny covering reminds one of that of the Urchin, and

the term *Echinodermata*, which is applied to the entire order, does no more than express in a single term the fact that the animal has a coat, or skin, or covering, resembling that of the hedgehog. In the annexed figure (Fig. 40) the prickles are shown in their natural condition on the right-hand side; on the other they are removed, so as to exhibit the structure and appearances of the part underneath.

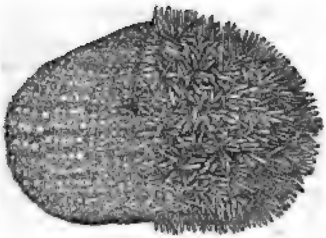

Fig. 40.

The hard calcareous covering, or "shell," as it is often, but incorrectly termed, is well deserving of minute and careful examination. We find Sea-urchins of very different sizes. How is the "shell" enlarged to meet the acquirements of the growing animal? It is composed of a multitude of pieces, accurately fitted to each other; a living membrane supplies the shelly secretion, and deposits it round the edges of every separate piece; each piece maintains, therefore, its relative proportion to all the rest, and while the bulk of the entire mass is augmented, the characteristic outline of every part is preserved.

It may not prove uninteresting to advert to some other points of structure. "In a moderate-sized Urchin I reckoned," says Forbes, "sixty-two rows of pores in each of the ten avenues; now, as there are three pairs of pores in each row, their number, multiplied by six and again by ten, would give the great number of 3,720 pores; but as each sucker occupies a pair of pores, the number of suckers would be half that amount, or 1,860. This structure in the egg Urchin is not less complicated in other parts. There are about 300 plates of one kind, and nearly as many of another, all dovetailing together with the greatest nicety and regularity, bearing on their surfaces above 4,000 spines, each spine perfect in itself, and of a complicated structure, and having a free movement on its socket. Truly the skill of the great Architect of Nature is not less displayed in the construction of a Sea-urchin than in the building up of a world."

The Sea-urchins are, like the Cross-fish, furnished with delicate retractile suckers, and move by the joint action of these suckers and of the spines. If any of my young friends, during their summer sojourn at the sea-side, would pick up two or three Sea-urchins, just when they have been left on the beach by the retiring tide, and would place them in a milk-pan, or other shallow vessel filled with sea-water, they will form a better idea of their mode of progression than from any description. The annexed figure (Fig. 41) represents the dental apparatus, more popularly called "Aristotle's Lantern." So far among the *Echinodermata* we have met nothing of the kind; it is not found in all genera of Sea-urchins, but appears suddenly developed, and as suddenly withdrawn. Yet it is in its arrangements most admirable and unique.

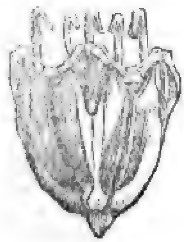

Fig. 41.

The five sharp-pointed teeth at the lower part break up the shell-fish on which the Sea-urchin feeds. That they may not be worn away by such severe

duty, they are at the points as hard as enamel, and of a softer and fibrous structure above; and, like the teeth of the gnawing animals, are always growing. The triangular pyramidal pieces above are smooth on the outer surface, but on the other two sides they are finely grooved, as if with a file. It is obvious, therefore, that there are ten surfaces for the grinding down of the food, and that these are so arranged that they work in pairs. There is also a very complete arrangement of muscles, to bring into full operation this effective piece of machinery, which has here been only in part described.

In both the Star-fishes and Sea-urchins the blood is aërated by the free admission of sea-water into the interior of the body. At one period of the year the Sea-urchin, if cut across, exhibits only a delicate tubular membrane going twice round the interior, and forming, in fact, both stomach and intestine. But at a later period, or towards autumn, much of the vacant space is found filled with large masses of ova or eggs. These were much prized by the ancients, who dressed them in various ways, and they are eaten, in many parts of the world, at the present day. Such of my young readers as have read Byron's narrative of the loss of the *Wager* in 1740 may be reminded of his description of the young Indian woman taking a basket in her mouth, jumping out of the boat, diving to the bottom, and bringing it up filled with sea-eggs, for by that name Sea-urchins in egg are referred to.

Leaving now the *Echinidæ*, we come to another family, the *Holothuridæ*, in which the body, instead of being rough or prickly, is soft like that of a snail. The *Holothuria* has suckers like the Star-fish or the Sea-urchin; but it can also move by the contraction and expansion of its body in the same manner as a worm. The English term "Sea-cucumber" gives some idea of the appearance; and it will be still better understood by a reference to Fig. 42, which represents the largest species yet discovered in the British seas (*Cucumaria frondosa*). The strangest thing about these animals is the manner in which they part with the most important organs, casting them away as things of no account. Sir John Dalzell states, from his own observation, that after this had been done so thoroughly that the body remained like an empty sac, in a few months all the lost parts were reproduced. This is the more remarkable, as the anatomical structure is remarkably complex. Sir John informs us that a Holothuria has produced five thousand ova in the course of a single night.

Fig. 42.

When parts so important as the tentacula, the mouth, the œsophagus, and the intestine are wilfully discarded by the Holothuria, we can scarcely expect it will remain true to its proper form of body. Could our vagabonds, whose descriptions fill the *Hue and Cry*, acquire from this humble marine animal the power of changing, like him, their form and dimensions, they would have a better chance of escape. The very species which is here figured (Fig. 42) is sometimes pleased to pull in his tentacula, and assume a perfect oval figure; and again, when the whim seizes him, he can contract towards the middle to such a degree, that he reminds one of an hour-glass.

These animals come but rarely under our notice, and can only be regarded

by us as objects of philosophical interest. But in other parts of the world they are sought for with great avidity, and even constitute an important branch of commerce, under the name of *trepang*, or *bêche-de-mer*. They are sold to the Chinese, along with sharks' fins and edible birds'-nests. Captain Flinders fell in with a fleet of Malay proas engaged in this traffic at the English Company's Islands, north coast of New Holland, near the Gulf of Carpentaria (1803); and was informed that sixty proas, belonging to the Rajah of Boni, and carrying one thousand men, had left Macassar, with the north-west monsoon, two months before, on an expedition to that coast, for the purpose of collecting the *trepang*. The process of curing is a simple one. The *trepang* is split down one side, boiled, pressed with stones, then stretched open with slips of bamboo, dried in the sun, and afterwards in smoke; it is then fit to be put away in bags.

We come now to the last family of the Star-fishes, the *Sipunculidæ*, or Spoon-worms. They are the outliers of the Radiate kingdom, and have abandoned the costume and external appearance of their relatives, and put on that of worms, true subjects of the Articulated kingdom. But even here an examination of internal structure shows where the real affinity exists. They are not furnished with suckers; and they move as worms do, by the expansion and contraction of different segments of the body. Some are found under stone; some burrow in sand; and some select as their mansion an empty univalve shell. Such is the practice of the species here represented (Fig. 43, *Sipunculus Bernhardus*), resembling in this respect the Hermit crabs. Its colour is white; the animal can extend itself to a length of three inches, can retract the entire proboscis at pleasure, and change at will the proportions of the body itself.

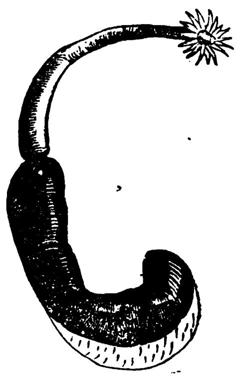
Fig. 43.

We should hardly expect that animals so lowly in their organization, so harmless to man in their habits, as the *Echinodermata*, would be made the objects of either superstitious fears or practices. Yet when Dr. Drummond, the talented author of *First Steps to Botany*, was drying some specimens of the common Star-fishes, or Five-fingers, in a little garden at Bangor (Co. Down), he heard some children on the other side of the hedge say, "What's the gentleman doing with the bad man's hands? Is he ganging to eat the bad man's hands, do ye think?" It appears that the name they are known by there is that of the Devil's-fingers and the Devil's-hands, and that children have a superstitious dread of touching them.


Fig. 44.

There is another species, distinguished by the great regularity of its outline—the Butt-horn (*Asterias aurantiaca*, Fig. 44), and pretty generally distributed round our coasts. Of this Mr. Bean, of Scarborough, communicates to Professor Forbes the following singular superstition:—"Our fishermen call this species a Butt-horn. The first taken is carefully made a prisoner, and placed on a seat at the stern of the boat. When they hook a but (holibut) they immediately give the poor star-fish its liberty, and commit it to its native element; but if their fishery is unsuccessful, it is left to perish, and may eventually enrich the cabinet of some industrious collector."

CHAPTER XII.

RETROSPECT.

"What great events from trivial causes spring!"

In the preceding chapters I have led those who have journeyed with me over one of the great empires into which the Animal Kingdom is divided. Our path has lain among the Radiate animals; let us now glance back upon them, pause a little on their array, and ponder on the powers with which they have been gifted.

The first tribes that we encountered, the *Infusoria*, were made known to us only by the aid of the microscope; yet so far do calculations as to their size and numbers transcend the limited faculties with which we are here endowed, that, to use the words of Burke, "we become amazed and confounded at the wonders of minuteness; nor can we distinguish in its effect the extreme of littleness from the vast itself."

Next we were introduced to those who "shun the glare of vulgar light," and pass their lives within the bodies of other animals, the *Entozoa*. A strange and motley group—some of them more simple in their structure than the simplest polypes, others so highly organized that it is doubtful if they might not with greater propriety be classed among the articulated or jointed animals, such as worms and insects.

And then came the *Zoophytes*, surpassing in their reality all the wonders of classic fable; gifted with strange powers of increase, multiplying under treatment that would to other animals be destruction, investing with delicate lacework the frond of the huge sea-weed, and giving to the shallows of the tropical sea the beauty and variety of the most cultivated parterre.

Then passed we on to creatures, the *Acalephæ*, that seemed little else than masses of vivified sea-water. So frail are the tissues of their body, that they can be likened only to the web of the spider; so that the term *Arachnodermata*, expressive of this peculiarity, contrasts with that of the adjoining group, which bears the name of *Echinodermata*. At last, in our onward

progress, all radiated arrangements of parts or of outline disappeared, and we found ourselves among beings which presented the appearance, and even adopted the appearance, of worms.

It is, I hope, distinctly understood that the classification and arrangement that has been adopted is not that which is *absolutely* best, but only that which was the best according to the state of science at the time such classification was adopted. Recent accessions to our knowledge of structure and transformations point the way to changes of arrangement; for when a real affinity has been shown to exist, those animals which are closely allied to each other cannot long continue to be arbitrarily separated. The boundaries of different groups will therefore, at a future time, be most probably enlarged or diminished; nay, the position of certain groups altogether changed.

It must be recollected, however, that all such changes are demanded by the progressive advance of knowledge. Genera, families, and orders are human inventions, and liable to the mutability of all human affairs; but species have a real existence in nature, and they remain unchanged, though we change the manner in which we group them together.

I would not like my readers to be satisfied with knowing the little that is here put down for them. I would hope that in other books, and in the great field of nature, they would learn and observe far more than I can impart. Nor should I wish them to stop even then—to be content with a knowledge of what they read or what they see, and go no further. My favourite pursuit would fail in its highest ground of recommendation, did it stop there. It should be suggestive of long trains of thought, rising from the creature to the Creator. How is it possible we can contemplate the varied means of reproduction observable among the Radiate animals, and not feel that an Almighty Power has been at work, not only in forming them originally, but in gifting them with the means of increase, and in extending a watchful care over their defenceless young? We see on all sides a bountiful provision made for their safety, so that not one species, however humble, is allowed to perish until the period allotted for its continuance has been fulfilled.

If we turn our thoughts in another direction, and consider what great results are, under the providence of God, produced by agents apparently the most powerless, the coral isles of the Pacific offer a familiar and most striking illustration. But we may find another example among organisms still more minute, and living in our own seas and rivers. I allude to the *Infusoria*.

Among these are some which possess the power of withdrawing silex from the water, in which it is held in solution, and depositing it in a solid form, in varied, definite, and very beautiful patterns. The great improvements made within the last few years in microscopes, and the greater attention paid to these "minims of nature," have enabled accurate observers to ascertain that their mode of reproduction is precisely analogous to what prevails in certain *algæ*, or water plants, and hence the inference is drawn that the *Diatomaceæ*—for so these organisms are named—more properly belong to the vegetable than to the animal kingdom. It is difficult to draw a line rigidly dividing the animal and the vegetable creation; there is a border territory, where settled and recognized government does not prevail. There the zoologist may make a foray, and capture and drive off the booty on which he seizes; and there the botanist may make sharp and sudden repri-

sal, regain the prey, and successfully carry off with him entire species, which the zoologist had complacently regarded as his own. On such a territory let me for the present place the *Diatomaceæ:* whether they be animal or vegetable, they will equally well establish the point to which I wish to call attention, that organisms the most minute may become the instrument of great and permanent changes.

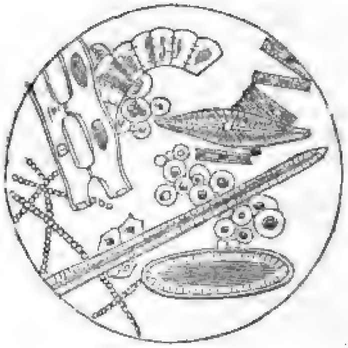

Fig. 45.

Silex is found in all waters, though in very different proportions, and once separated from it in a solid form, becomes indestructible. The *Diatomaceæ* deposit the silex on the tissues or membranes which they possess, and hence give to them regular patterns of extreme delicacy and beauty.

The annexed figure (Fig. 45) represents some native species, and will convey an idea of the variety of forms they exhibit.

The *Diatomaceæ* exist in fresh water, in brackish water, and in sea-water. They are found in rivers, in lakes, in dripping wells, and in snow-fields, and are extremely abundant both in the arctic and antarctic seas. There is no part of the world in which they are not silently at work; in remote periods of the past history of our globe they appear to have been equally diffused: the proofs of their existence remain as fossil deposits.

Ehrenberg discovered that the tripoli, or *polierschiefer*, used at Berlin, was entirely composed of these silicious shells. He regarded the organisms as animal, and states that so rapid is their increase, that two cubic feet of tripoli might be formed in four days from one individual. At Bilin, in Bohemia, there is a single stratum of this substance not less than fourteen feet thick, forming the upper layer of a tripoli hill, in every cubic inch of which Ehrenberg calculates there are *forty-one thousand millions* of one species. The city of Virginia is built on a deposit of *Diatomaceæ* twenty feet in thickness. They are now, insignificant as they appear, filling up the mouths of rivers, and gradually, as marine deposits, affecting the ocean bed.

When the antarctic voyagers reached the icy walls to which they gave the name of the Victoria Barrier, it was found embrowned with *Diatomaceæ;* and as they sailed along the Barrier, the soundings which they took made them aware of the existence of a bank extending for four hundred miles, and composed almost wholly of their silicious skeletons. Floating masses of ice yielded them in millions, and in many places they formed a scum on the surface of the sea. Darwin, a high authority, states that fine dust which fell elsewhere on the deck of a ship at sea, was found, on examination with the microscope, to be composed of *Diatomaceæ*. From their universal diffusion we cannot doubt that they are the unseen, and yet resistless agents of mighty changes, and of beneficial results, which we are unable to comprehend.

Let us pass on to another topic. It is a summer eve: we are strolling by the shore, with the pleasant murmur of the sea sounding in our ears, the fresh air upon our cheek, the glories of a summer sunset in the western

sky. Gradually the light fades, and new tints, each beautiful and glorious, enrich the azure vault. The stars begin silently to peep out, and night steals over the landscape. Yet we turn not homewards; we find the gentle heaving of the sea, calm as a sleeping child, inexpressibly charming and tranquillizing. We hear the sound of oars—a boat approaches; but what a glorious sight! About its prow curl waves of fire, a long train of light follows in its wake, and the water that drips from the oar is converted into diamond sparks. We hail the boat and step on board; new wonders greet our sight. Each passing breeze lights up a track of splendour. Whenever the water is disturbed it seems converted to innocuous flames; and, deep below the surface, the large jelly-fishes shine with their own peculiar and beautiful luminosity.

This phenomenon has not escaped the accurate observation of Crabbe, by whom it is thus noticed in his poem of *The Borough*:—

> "But now your view upon the ocean turn,
> And there the splendour of the waves discern;
> Cast but a stone, or strike them with an oar,
> And you shall flames within the deep explore;
> Or scoop the stream phosphoric as you stand,
> And the cold flames shall flash across your hand;
> When, lost in wonder, you shall walk and gaze
> On weeds that sparkle, and on waves that blaze."

It has been happily introduced by Sir Walter Scott, in his *Lord of the Isles*, under circumstances that give increased interest and vividness to the scene described.

The phenomenon is said to be still more splendid in tropical seas; but without adverting to the narrative of navigators, by whom in glowing language it has been described, let us ask, How is it occasioned? What gives origin to the luminosity of the sea?

Darwin expresses his opinion in the following words:—"Observing that the water charged with gelatinous particles is in an impure state, and that the luminous appearance in all common cases is produced by the agitation of the fluid in contact with the atmosphere, I have always been inclined to consider that the phosphorescence was the result of the decomposition of the organic particles, by which process (one is tempted almost to call it a kind of respiration) the ocean becomes purified."

Elsewhere, however, the same eminent naturalist observes, in speaking of the Atlantic ocean, "When the waves scintillate with bright green sparks, I believe it is generally owing to minute crustacea." Certain *polypes*, as has been already mentioned (p. 291), give out light when irritated. Some *Annelids* and *Mollusca* possess a similar power, but minute *Acalepha*, or Jelly-fishes (p. 313), of various kinds, are the great agents in thus illuminating the surface of the ocean. According to the views now most generally entertained, it is to the abundance of *life*, not to decay and death, we must attribute this luminosity. And if each spark be a unit in the amount of animal existence, how vast must be the aggregate! How great the profusion of animal life throughout the waters of the ocean!

We saw, when treating of the *Infusoria*, that millions might be contained in a single drop of water (p. 280). When considering the *Polypes* we found that they sometimes numbered eight millions of individuals on a single zoophyte (p. 291). We now find that microscopic *Acalephæ* are diffused

throughout the sea-water, and, notwithstanding their individual minuteness, give origin to one of the most striking phases of the "vasty deep." All this abundance of life connects itself with the humble *Radiata* we have been considering. Can we doubt that happiness is co-existent with life?—that enjoyment has been graciously bestowed wherein life in any of its varied forms has been given?

It may assist us in forming correct ideas of the amount of microscopic life existing in vast tracts of the ocean if we turn to a calculation given by Scoresby in his *Arctic Regions*. He found that the peculiar green colour of the water of the Arctic sea was owing to the multitude of minute *Medusæ* which it contained. "They were," he says, "about the one-fourth of an inch asunder. In this proportion a cubic inch of water must contain 64; a cubic foot 110,592; a cubic fathom 23,887,872; and a cubical mile 23,888,000,000,000,000."

This discoloration extends over an extent of perhaps twenty or thirty thousand square miles, so that the mind sinks overpowered by any attempt to estimate their numbers. Viewed with reference to the whales and other inhabitants of these seas, how vast is the supply of food derived from this source! And it is obvious that by affecting the objects of his pursuit, they exercise a certain and not very remote influence on man himself.

CHAPTER XIII.

SUB-KINGDOM—ARTICULATA.

ARTICULATED, OR JOINTED ANIMALS.

"Whatever creeps the ground,
Insect or worm: those waved their limber fans
For wings, and smallest lineaments exact
In all the liveries deck'd of Summer's pride,
With spots of gold and purple, azure and green;
These as a line their long dimensions drew,
Streaking the ground with sinuous trace."—MILTON.

IF a person not familiar with natural history terms and classification were asked to give an example of a jointed animal, he might possibly name the cow or the horse, and assert that he himself was included in the same category. But, however paradoxical it may appear, an animal with joints is not necessarily a jointed animal in the natural history acceptation of the term. We have been treating of invertebrate animals, and still continue to do so. The horse, the cow, and the man are of course excluded, as belonging to the higher or vertebrate division. Our business, at present, is with creatures destitute of a skull and back-bone, not rayed or radiated like those hitherto under consideration, but exhibiting in their bodily structure a number of joints or distinct segments, such as we see in the lobster.

An Articulated or Jointed Animal—for both terms express the same thing—is an invertebrate animal, with the body jointed, and generally exhibit-

ing a repetition of rings or segments of similar appearance as in the earthworm and the centipede. The nervous system, in its arrangement, is not less symmetrical than the external figure. It consists of a series of small centres or swellings of nervous matter, called ganglion, connected by threads, and extending along the lower side of the body; from these are given off the nerves which proceed to the extremities. The brain is represented by a more considerable mass of nervous matter, which surrounds the throat in the form of a ring.

It is by these characteristics that the Articulated Kingdom is distinguished from the Radiated. The tribes inhabiting the borders of the two countries are so much alike, that, judging merely from external appearance, we know not to which they belong. Thus we have seen that the family of the *Sipunculus* is, in reality, allied to the Star-fishes by its structure, yet seems to belong to the present class from its worm-like aspect.

The Articulated animals are arranged in five clasess, namely—

I. *Annellata*, Leeches, Earth-worms, &c.
II. *Cirripeda*, Barnacles and Acorn-shells.
III. *Crustacea*, Crabs, Lobsters, &c.
IV. *Insecta*, Beetles, Bees, Butterflies, &c.
V. *Arachnida*, Spiders, Mites, &c.

CLASS I.—ANNELLATA.

LEECHES, EARTH-WORMS, ETC.

The Latin word *annellus* means a little ring; hence the term *annelid* denotes an animal which, like the earth-worm, has the body composed of a series of little rings. Each of these seems externally but a repetition of the adjoining one, *alter et idem*. But, in reality, it is not so, for different portions of the body perform very different functions. In the head, and there only, are placed the organs of sense, such as they are; and both the digestive and the circulating system have their own respective centres. Such being the case, we should inflict a grievous wrong upon one of these creatures if we cut it in twain, and supposed that the severed parts would each take upon itself the functions of the perfect animal.

Fig. 46.—LEECH.

Among this class are some very respectable families, that confine themselves exclusively to animal food; and there are others not less ancient, that live on vegetable diet, and turn up their noses at the juiciest flesh-meat imaginable. There are others, again, possessing an aldermanic relish for fish, flesh, and fowl, and for vegetable condiments also, and to them nothing they can swallow comes amiss. If the nutritious matter be mixed with sand it is of no consequence; they adopt the simple process of gulping all down, digesting what is digestible, and rejecting the remainder.

In most of the annelids the blood is red; they have, therefore, been called "red-blooded worms," and by the French naturalists, "vers à sang rouge." This character is, however, by no means universal; there are some species in which the blood is of a pale yellow; there are others in which it is of an

olive green. The same importance is not, therefore, attached to the mere colour of the blood as was attributed to it by Aristotle, and by some writers in more modern times.

The breathing organs of this class present very considerable modifications. In some species they are adapted for extracting oxygen directly from the atmosphere. In some, which live in water, that fluid is admitted into the interior of the body by minute apertures, and received in a series of chambers, which perform the functions of internal gills. In others the gills are external, and appear as ornamental appendages on different parts of the body, or as plumes of great beauty surmounting the head. The snowy feathers bending on the head of the ball-room queen, or waving on the steel helmet of the warrior, serve but as decorations; the graceful, and, at times, brilliant plume displayed by the annelid, serves, not for ornament solely, but performs the important function of a respiratory organ.

And now that I have, by this comparison, freed my thoughts from the strict trammels of science, I must tell a little tale to my younger readers, and lead them to observe similar facts for themselves.

It was the month of March. Some of my children had brought home frogs' spawn, and we had been watching its progress until the young tadpoles had burst their prison-house, and were swimming about. It became a question how they were to be fed, so, accompanied by some of the youngsters—I mean some of the young bipeds, not the young tadpoles—I sallied forth. We left the town a mile behind us, and got into the country, and amid green fields and hedgerows, full of indications of the coming spring, we sought the required nutriment. It consisted of certain aquatic plants—fresh-water algæ—which we found in the clear water of the ditches. A mass of it was gathered and transferred to a tin botanical box, and we trudged merrily homewards, the object of our expedition having been accomplished. On our arrival we got a couple of glass vessels containing some water, and transferred to them the contents of our box. Almost immediately some small crustacea made their appearance, like animated specks swimming briskly about. Then some water-beetles got themselves disentangled from the vegetable mass, and began their movements; then a great worm showed part of its body, and vanished. It came forth again, contracted its body in a peculiar manner, fixed itself to the side of the glass by one extremity, flung the other end for a moment upwards, then applied it also to the glass, and moved the other towards it. It was not a worm at all—it was a horse-leech!

Great was the delight at this discovery, endless the expressions of wonder as the leech paced along the plants, each end of its body acting in turn as a sucker, and becoming a point of attachment. The sucker was a broad, expanded, saucer-shaped disc. None who were then present will fail to remember, that whenever a worm-like creature with such a sucker at each end of the body is found, that animal is a leech. The suctorial discs distinguish it from other annelids.

When we gaze for some time on an active leech, observe the variety of movement which it exhibits, and the sudden change of form of which it is capable, we are led to ask how all this is accomplished. The anatomist answers the question. He tells us that the body is furnished with three distinct series of muscular fibres. The outer one forms the external surface of the rings of the body; its direction is transverse. The inner one is com-

posed of fibres, which are longitudinal, or run lengthways. The intermediate set is crossways, or diagonal, so that by their combinations every possible variety of movement is obtained.

The horse-leech spends the winter in the soft mud in the bottoms of drains and ditches, and rouses to fresh activity with returning spring. Unless specially sought for, it comes but seldom under the notice of those who live most generally in populous towns or cities. Let us turn, therefore, from it to the medicinal leech (*Hirudo medicinalis*), a species more generally known, and whose services are very highly and justly appreciated.

To some of my readers the leech is associated with sickness and suffering—with the stillness of the sick room, the visits of the physician, the bleeding, the sponging, and other matters incidental to such a period. "Let such bethink them" that the leech comes as the healer, not as the promoter of disease; as the benefactor, not as the tormentor; and if regarded in this light, or viewed, if not with complacency, at least without feelings of dislike, I may perhaps not try the patience of my young friends too far if I call attention to two or three interesting peculiarities of structure, or at least what appear to me to be so.

The leech being formed to get its food by suction, must have its eyes so placed as to guide the lips, by which the suction is to be performed, to the proper position. Were I to ask where, for such a purpose, the eyes should be fixed, some merry joking little urchin might answer, "On the lip itself," that being, as he conjectures, the most unlikely possible place for eyes to be found. Yet, in this instance, the supposed absurdity turns out to be the sober fact. The eyes are on the upper margin of the lip; they are ten in number, and may easily be distinguished by the aid of a magnifying-glass of moderate power.

The bite of the leech leaves a triangular-shaped mark. How is this occasioned? The mouth is itself triangular, and has three crescent-shaped jaws, the margin of each of them being furnished with sixty small teeth (Fig. 47). Each of these teeth resembles, therefore, a small semicircular saw; and the skin being stretched out by means of the suctorial lip, becomes quite tense, like the head of a drum; the saws being then brought into play by bundles of muscular fibre adapted to that purpose, the characteristic tri-radiate bite is produced.

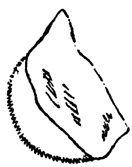

Fig. 47.

We have read in our boyhood of the camel, "the ship of the desert," and of its wondrously-formed stomach, in which water remains unchanged. But few of us have supposed that the leech has a stomach not less extraordinary. It is divided into eleven compartments, and in the first eight of these the blood may remain for months unchanged either in colour or fluidity, the creature merely allowing so much to pass into the alimentary canal as is actually necessary to preserve its existence.

All of these peculiarities of organization offer matter for remark; but instead of any comments of my own, I shall lay before my readers a reflection made by Professor Rymer Jones. "On contemplating," says he, "the singular dental apparatus found in the medicinal leech, and considering the nature of the food on which it usually lives, it is difficult to avoid arriving at the conclusion that such a structure, which is indeed only met with in one or two species, is rather a provision intended to render those creatures subservient to the alleviation of human suffering, than necessary to supply

the wants of the animals themselves. In the streams and ponds which they usually inhabit, any opportunity of meeting with a supply of the blood of warm-blooded vertebrata must be of rare occurrence, so that comparatively few are ever enabled to indulge the instinct which prompts them to gorge themselves so voraciously when allowed to obtain it."

We must not, however, if we would rightly understand the structure and habits of this tribe, restrict our view to those which are seen at home; we must extend it to such as are found in other countries. In Egypt there is a species which was a source of annoyance to the soldiers of the celebrated French expedition, and which occasionally was a source of injury to the horses, by getting into their nostrils, and then inflicting their customary wound. Their full power as tormentors, under certain circumstances, and in restricted localities, is nowhere so well exemplified as in the island of Ceylon; and to it I must now direct your attention.

The leeches of Ceylon are extremely diminutive when compared with our native horse-leech, or even with the medicinal leech. Their length is about a couple of inches, their thickness not much above that of coarse hair or packthread, but when distended with food equal to that of a quill. But though pigmies in size, they become to the traveller a serious source of annoyance from their countless numbers. They exist by myriads in the moist herbage, and fix themselves unnoticed on the feet and legs, so that the unfortunate wayfarer occasionally finds them bathed in blood before he is aware that he has been attacked. The European provides himself with a pair of stout boots, and stalks along congratulating himself on his impunity. After a time a strange moisture manifests itself, and putting down his hand, he discovers that his assailants have scaled the fortress and gained the citadel—they have got within the boots. Wiser by experience, he now ties his trousers firmly round the upper part of the boots, and resumes his journey. The heat is great, but the perspiration seems peculiarly abundant about the back of his neck. He applies his fingers to the part, and finds, to his dismay, that it is covered with blood; one of his persevering assailants has climbed up his back, and feasted itself to satiety on his neck! Perplexed at this fresh assault, he stops to ascertain the extent of his calamity, and when he raises his eyes, beholds, to his dismay, the whole herbage around him alive with leeches. Each one raises itself erect, as if for the purpose of observation, and directs his course right towards the intruder on

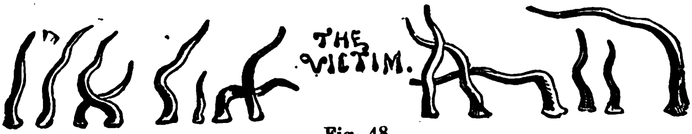

Fig. 48.

his solitude (Fig. 48). Each moves by rapid, yet measured paces, as a surveyor might be supposed to do if engaged in estimating distance. The traveller sees himself the focus of attraction—his assailants are converging towards him—smitten with sudden terror, he starts from his resting-place, and seeks safety in flight.

A friend of mine, who has been all his life a very accurate observer, has favoured me in one of his letters with the following very graphic account of

the Ceylon leeches. I hope it may afford to my readers the same amount of amusement and information that I have myself derived from its perusal.

"Some of them are as fine as needles; all of a light clear brown, with the usual yellow or pale stripe. Leaves fall from the trees on the jungle paths, and it is among these leaves, at parts where the jungle overhead is so thick that the leaves are always moist, that they principally abound; but after a shower, even the places formerly driest have plenty of them. In the mornings and evenings the grass all over the cleared country abounds with them. They are not found near Columbo, that is, not within fifteen or twenty miles of it; the same is the case in many other parts of the low flat country, where the moisture is too rapidly and too completely dried up. Persons say that they drop upon you from the trees. I do not believe this, and I think the error has arisen from finding them on the neck, to which they have ascended in their search of a hole to creep in by. I have often watched their manœuvres, when I chanced to be walking the last of a party. Look ahead, and not one is to be seen; but the moment the first person disturbs the leaves, multitudes of little heads appear, as if the ground abounded with the nests of polypi, twisting their tentacula about. The celerity with which they attach themselves to the boot or shoe of the next comer would surprise you; the instant they feel it, they let go their hold of the leaves, are transferred to the shoe, and then on they go in search of any cranny for entrance which the unwary traveller may have left. The variety of their attitudes while thus engaged may be imagined rom the annexed sketch (Fig. 49.)

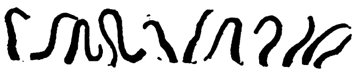

Fig. 49.

You never feel them until, having saturated themselves with blood, their weight begins to make them drag on the wound; when empty they have no weight, and do not drag. Their mouth is placed obliquely to the axis of the body. I could perceive no teeth; the wound is irregular, extremely small, and rather elongated; the disc at the postal extremity is flat and round, perfectly smooth, and the body contracts rather suddenly above it. On going along with these gentry adhering to you, of course you strike off as many as you can conveniently get at, but every two hundred yards you are forced to stop wherever you can find a large stone to stand on, or a bare patch of the path, so that you can guard against any fresh attacks, and then you begin to weed off. The natives use a half lime (lemon), the acid juice of which curls them up in a twinkling; or a drop of saliva from their mouths, when chewing tobacco, has the same effect. The planters touch them with the ash at the lighted end of a cigar, or tie a piece of the dried leaf of tobacco dipped in water across their shoe. Either mode is perfectly effectual, and they twist about in fifty shapes, instantly letting go. In travelling through the jungle, the planters use leech-gaiters, which have feet like a stocking, are made of duck or coarse calico, and tie above the knee. I tied my trousers tight round my boots, or better still, the boots tight round the trousers, as they seldom descend, but still keep ascending: this, however, is not always to be depended on. Horses and cattle get quite mad with them, and stamp like devils. There is one nearly allied species, larger and longer, which frequents the edges of pools, and gets into the nostrils of black cattle, where they stick for weeks, often destroying the animals, which sink from loss of blood and the local irritation: it is of a

sordid brown, and has no lateral band. I forgot to say that at every step the jungle-leech takes, it pokes its nose up in the air, moving it about as if in search of a whiff of wind from the unhappy victim; and I never could ascertain by what faculty they became cognizant of his presence, as they seem to come up in all directions, irrespective of what way the wind blows, from a distance of about eight or ten feet, which they could traverse in about as many minutes. When they have got their full supply of blood, they do not drop off, unless inconvenienced by the friction of the clothes against them, but seem disposed to stick until they are ready for a fresh feed. They seem to select, when they can, the most tender, juicy parts, so that after they are detached the wound bleeds very freely, your stockings being often saturated. In the same way they always seek to attach themselves to the horse's fetlock, and get to the inner side of his leg above; and as the Indian horses have all extensive cutaneous circulation, like our high-breds, I have often traversed the jungle with the legs of my grey horse brilliant red from the knees down, with here and there a white longitudinal streak—a very cardinal!"

CHAPTER XIV.

LEECHES AND EARTH-WORMS.

I HAVE been spinning what sailors would call "a long yarn" about leeches, but I have not yet done with them. They stick to me, not bodily, but mentally. The contemplation of their structure and habits suggests the reflection, "Surely these humble annelids exercise, under certain circumstances, an important influence over man himself." A gentleman who resided for some time among the coffee plantations of the island of Ceylon told me that when he descended to the lower grounds, and wanted in the course of his wayfaring to eat his dinner undisturbed by the leeches, he found the best plan was to wade into a river or other water, sit down on a stone, if he could find one, and there enjoy his repast secure from molestation. Let some who live at home, and "fare sumptuously every day," think how great must be the annoyance that could make such a situation as a stone in a river's bed a place of comfort. A satirist, with a little stretch of imagination, might tell us of some warrior leech returning to his companions in the jungle, and describing, in a tone of exultation, how he had scaled the defences, sucked the blood of a pale-faced son of Europe, and driven him from their domain; or how a medicinal leech had collected her descendants around her, and pointed out how carefully the great "two-legged animal without feathers" attended to their wants, and at times prepared for them a banquet on the fairest and plumpest of his own species. A grandmother leech thus detailing the results of her experience might inculcate her conviction that man was surely created for the especial benefit of leeches!

Passing from these topics, let us glance at the signification of the word leech in times gone by. It was not confined to the annelid, but applied also to professors or practitioners of the art of healing. Thus we have in Spenser—

"The learned *leech*
His cunning hand 'gan to his wounds to lay."

Elsewhere the same great poet has introduced the same epithet in lines of deep significance:—

"A *leech* which had great insight
In that disease of grieved conscience,
And well could cure the same; his name was Patience.

The question may naturally be asked, Did the man derive the appellation from the annelid, or the annelid from the man? A friend, who is in my eyes a learned pundit in all such matters, informs me that the epithet in both cases was derived from the same root—a Saxon word which signifies "to heal." The old word "leech-craft" denoted, therefore, the art of healing; and its occurrence in some of our old metrical romances tempts me to linger on my way, and couple this part of my subject with the legendary and historic lore of other days.

Among the ancient Germans the women followed the armies to the field, and dressed the wounds of the combatants. Ladies figure not unfrequently as surgeons in the romances of the twelfth and thirteenth centuries, as well as in the poems of Ariosto, Tasso, Spenser, and later bards. The following passage occurs in *Ywaine* and *Gawin*, written in the reign of Richard II.:—

"Twa maydins with him thai left,
That wele war lered of *lechecraft*,
The lorde's doghters boththai wore."

Again, in the celebrated *Morte d'Arthur*, we read that the knight Sir Tristram, having been sorely wounded with a poisoned spear, King Marke sent "after all manere of *leches* and surgeons, both unto men and wymmen, and there was none that wold behote hym the lyf." And in the ancient and popular ballad of *Sir Cauline*, the king applies the term "leeche" to his daughter, when he calls upon her to exercise her skill on behalf of the wounded though victorious knight:—

"Come down, come down, my daughter deare,
Thou art a *leeche* of skille;
Farre lever had I lose half my lands,
Than this good knight should spille."

It is under circumstances somewhat similar that Rebecca is represented as taking charge of the Knight of Ivanhoe. Sir Walter Scott, while he recounts the fact, invests it with new tenderness and elevation. "The idea," he says, "of so young and beautiful a person engaged in attendance on a sick-bed, or in dressing the wound of one of a different sex, was melted away and lost in that of a beneficent being, contributing her effectual aid to relieve pain, and to avert the stroke of death."

But *revenons à nos moutons*. Let us quit both poetry and romance, and learn what arrangement or classification of the annelids has been proposed by Cuvier, and by others who, like him, we regard as our "very noble and approved good masters."

By Cuvier they were divided into three orders, distinguished by the nature and position of their organs of respiration. In the first of these (*Abranchia*)

there were no external gills; in another, the respiratory organs were at the anterior extremity of the body (*Tubicola*); in the third, they were placed along the back (*Dorsibranchiata*). Dr. Milne Edwards, the eminent pupil of Cuvier, made, however, an important change in the system laid down by his great master. He divided the first of these groups into two, thus separating the leeches from the earth-worms. The suctorial discs at either extremity, to which reference has already been made, distinguish the leeches from all others belonging to the class. The absence of these discs, and the presence of a number of minute and almost imperceptible bristles, which assist in progression, form good distinctive characteristics by which the earth-worm and its allies are easily recognized. Its very name implies that it lives in the earth, or, to adopt a more learned mode of expressing the same idea, that it is "terricolous." Others live in the sand of the sea-shore, but the term just used is applied to both.

Perhaps some of my young friends are fond of puzzles and perplexing questions. If so, I would ask them to string together three terms, which could define a leech, and suggest one characteristic habit. "A leech is an —Do you give it up?—An *Abranchial suctorial Annelid.*" They may, perhaps, amuse themselves by bearing those three terms in mind, repeating them, and recollecting what they express. If they do so, they will have a clear idea of the characteristics of Order I., the ANNELLATA SUCTORIA—that is to say, of the leeches. And as we have already been attending to their structure and habits, we now bid them good-by, and proceed to—

ORDER II.—ANNELLATA TERRICOLA.

"Whoever," says Professor Rymer Jones, "has attentively watched the operations of an earth-worm, when busied in burying itself in the earth, must have been struck with the seeming disproportion between the laborious employment in which it is perpetually engaged, and the means provided for enabling it to overcome difficulties apparently insurmountable by any animal, unless provided with limbs of extraordinary construction, and possessed of enormous muscular power. In the mole and the burrowing cricket we at once recognize, in the immense development of the anterior legs, a provision for digging admirably adapted for their subterranean habits, and calculated to throw aside with facility the earth through which they work their way; but in the worms before us, deprived as they appear to be of all external members; feeble and sluggish even to a proverb, where are we to look for that mechanism which enables them to perforate the hard surface of the ground, and to make way for themselves, in the hard and trodden mould, the pathways which they traverse with such astonishing facility and quickness?

The explanation is to be found partly in the form of the head, which pierces the ground like a wedge, and partly in the minute bristles with which every ring of the body is endowed. If we pass our hand along the body of the earth-worm, from the head backwards, we are scarcely aware of their presence; but if we reverse the movement, they are at once perceived. This arises from the hooked form, and from the points being directed towards the tail. They take a firm hold on the ground, prevent any retrograde movement, and afford the necessary support for the next advance.

The word *seta* means a bristle; *setigerous*, bearing or carrying bristles. Substitute this word for "suctorial," in the definition of the leech, and the same terms with this one alteration will apply to the creatures now under consideration. The earth-worm is, therefore, an "abranchial setigerous annelid."

The alimentary canal is straight, and very capacious. It is generally found filled with earth; and hence an idea was at one time prevalent, that while other creatures were nourished from the animal and vegetable kingdom, the earth-worm derived its nutriment from the soil itself, or, in other words, from the mineral kingdom. This idea has been long since exploded; it is nourished not by the soil, but by the particles of decaying animal and vegetable matter contained therein. The mouth is furnished with a short proboscis, but is without teeth.

In White's *Natural History of Selborne*—that well-known and delightful volume—the amiable author remarks:—

"The most insignificant insects and reptiles are of much more consequence, and have much more influence in the economy of nature, than the incurious are aware of; and are mighty in their effect from their minuteness, which renders them less an object of attention, and from their numbers and fecundity. Earth-worms, though in appearance a small and despicable link in the chain of nature, yet, if lost, would make a lamentable chasm. For, to say nothing of half the birds, and some quadrupeds, which are almost entirely supported by them, worms seem to be the great promoters of vegetation, which would proceed but lamely without them, by boring, perforating, and loosening the soil, and rendering it pervious to rains and fibres of plants, by drawing straws and stalks of leaves and twigs into it; and most of all by throwing up such infinite numbers of lumps of earth called worm-casts, which, being their excrement, is a fine manure for grain and grass."

The opinions thus advanced by the Rev. Gilbert White, as to the importance and utility of earth-worms, have been confirmed by the observations of Charles Darwin, Esq., and were communicated by him to the Geological Society of London. Not only is the earth-worm useful in rendering the earth permeable to air and water, but it is also a most active and powerful agent in adding to the depth of the surface soil. In a pasture-field, which has long remained undisturbed, not a pebble will be seen, although in an adjoining ploughed field a large proportion of the surface may be composed of loose stones. This difference he attributes to the working of worms, and states his conviction that every particle of earth in old pasture land has passed through their intestines; and hence that, in some senses, the term "animal mould" would be more appropriate than "vegetable mould."

In some fields, which had a few years before been covered with lime, and in others which had been coated with burnt marl and cinders, these substances were found in every case buried to the depth of some inches below the turf, just as if, as the farmers believe, these materials had worked themselves down. From the continuous operation of these unseen and noiseless labourers, it has been estimated that the marl laid upon a field for manure would, in the course of eighty years, be covered with soil to the depth of thirteen inches.

Every one who has read Miss Edgeworth's tale of *Forester* will recollect how much, when in the employment of the gardener, he was pained by

cutting the worms in pieces with his spade. If some theories, once current, had been correct, this severing of the body should have caused only the multiplication of the individual; for it was believed that each part contained vitality, and became a perfect animal. The progress of knowledge dissipated this idea, and established the belief, that if an earth-worm be cut in two, only the piece which bore the head would be found alive after the lapse of a few hours; that on this segment a new tail would be gradually formed, and all appearance of injury, in time, effaced. It was also asserted that "if the division be made near the head, the body will remain alive, and will renew the head, and the head, with its few attached segments, will die." The statement that the head will be thus renewed has, however, been recently called in question in a *Report on the Structure, Habits, and Classification of the British Annelidæ*, by Dr. T. Williams. In this valuable communication it is stated that "the views which commonly prevail with reference to the regenerative powers of these animals are greatly exaggerated, if not altogether incorrect. A true head is never reproduced. If a worm of any species, the *Naisfiliformis*, for example, upon which the principal of my observations has been instituted, be cut into two parts, the anterior never re-constructs a true tail, nor does the posterior ever re-organize a true head; but both fragments will live for a considerable time, and the anterior extremity of the posterior fragment will suck in nourishment, swell in size, and become more vascular, while it preserves the distinctive organization of one of the middle rings of the body. It never re-forms a true head."

Such statements, founded on observations carefully repeated, upset our previous ideas, and show us how much remains to be done to gain a knowledge of even the most common of our native species. When I add that both leeches and earth-worms are hermaphrodites—that is to say, that each individual is both male and female, and that the eggs of the earth-worm are said to contain not unfrequently two yolks, and give origin to two individuals—my readers will see that even this humble creature may afford matter both for observation and thought.

CHAPTER XV.

TUBICOLAR ANNELIDS.

The third order of Annelids (*Annellata tubicolæ*) comprises those which do not move about like leeches or earth-worms, but lead a very sedentary life, encased in tubes which vary in their form and material. The encomium which was applied to the Roman matron, "manet domum"—she stayed at home—is strictly applicable to them; for they are, in their perfect condition, without the power of roaming, even if they had the inclination.

It is obvious that such worms cannot breathe by pores or sacs, like leeches or earth-worms. A modification of the breathing apparatus is consequently required; and accordingly we find it in the form of tufts of great elegance, arranged about the anterior extremity of the body (Fig. 50), where alone

they would be in contact with the sea-water. An example of this structure is furnished in the calcareous tubes which are common on dead shells, and which incrust, in a very striking and fantastic manner, old bottles and other articles which, after long immersion in the sea, are brought to light by the dredge. The figure here given represents one of those shells (*Serpula contortuplicata*), with a portion of the body protruded; but the whole procedure is so well described by Professor Rymer Jones, that I cannot resist quoting his words, and requesting my readers to verify for themselves the fidelity of his description:—

Fig. 50.

"If, while the contained animals are alive, they be placed in a vessel of sea-water, few spectacles are more pleasing than that which they exhibit. The mouth of the tube is first seen to open by the raising of an exquisitely constructed door, and then the creature cautiously protrudes the anterior part of its body, spreading out at the same time two gorgeous fan-like expansions of a rich scarlet or purple colour, which float elegantly in the surrounding water, and serve as branchial or breathing organs."

Fig. 51.

The shelly matter, of which the tube is formed, is of course secreted by the contained animal; but by what means is the *serpula* to guard itself against unwelcome visitors? How is the entrance of its sea-built citadel to be secured? Even this is to be provided for. At each side of the mouth is a fleshy filament; one is much larger and longer than the other, and is expanded into a funnel-shaped lid or stopper. This *operculum*, to use the more scientific term, fits the orifice of the shell, and thus forms a kind of door, which effectually shuts out all intruders, and is secured by a living mechanism more delicate than Chubb or Bramah ever constructed, or Hobbs attempted to undo.

It must not, however, be imagined that all the sedentary worms construct their mansions in the same style of architecture. There are some which do not supply a calcareous material for the edifice, but only the cement which holds the several parts together. The accompanying figure (Fig. 51) represents a species of *Terebella*, the outer covering being composed of shells, particles of gravel, and other substances, all small in size, but agglutinated together. At the sides of the head are the breathing organs, spreading out in tufts; and above are long and delicate feelers; these are regarded not merely as organs of touch, but as instruments for the capture of food.

We now come to the fourth order, which form in their habits a complete contrast to the tube-inhabiting species, and are gifted with such powers of locomotion, that Dr. Milne Edwards has bestowed on them the very appropriate term "Errantes," or wanderers. Perhaps no species is so well known as the "Lob-worm," or "lug" of the fishermen (*Arenicola piscatorum*, Fig. 52). On many parts of the coast it is abundant, and is dug out of the sand to be used as bait. The respiratory organs appear like tufts of an arborescent, or tree-like form, arranged along the back—not along the centre of it, but towards the sides. It was from the position of the gills along the dorsal aspect of the body that Cuvier applied to such worms the term *Dorsibranchiata*, and made this the name of the order to which they belonged.

Fig. 52.

The Lob-worm is so easily met with, that any of my readers who sojourn at the sea-side during the summer may dig out a few specimens, and examine them at leisure. When placed in glass vessels, and looked at carefully for a few minutes, the beautiful little respiratory tufts will be seen to be continually changing their aspect, being at one moment a bright red, and the next a duller tint, just as the blood is propelled into them or withdrawn, at the same time expanding or contracting in size. How wonderful and perfect must be the internal mechanism that thus manifests its presence! Just while you are gazing at the "lug," the anterior extremity suddenly changes its appearance, a large fleshy proboscis is suddenly extended, and as suddenly withdrawn. What can it be? Is it possible that the worm is putting out his tongue at you, and actually laughing you to scorn? Do not, gentle reader, let your *amour propre* be thus offended: the creature means no affront. The sudden exhibition that has frighted you from your "propriety" might be mistaken, in a dead specimen of the worm, for part of the alimentary canal; but its office is widely different. It can, at the pleasure of the animal, be turned inside out like the finger of a glove, and it then forms a most singular proboscis, used for seizing food, and not unfrequently armed with teeth of a singular construction, and which in some species assume a very formidable appearance.

Fig. 53.

It has been stated by Miller, a high authority on zoological matters, that in a species of Nereis (*N. prolifera*, Fig 53) he observed reproduction to take place by means of spontaneous division. The young is formed from the hinder part of the body of the parent, as shown in the annexed illustration—a segment of the body of the parent being converted into the head of the offspring; and this gradually becomes detached by the narrowing of the joint immediately above. Previous to its separation, the young sometimes forms another bud from its own body in the same manner, so that three generations have been observed thus united; and as the original tail of

the parent continues as the tail of its successive offspring, it seems, like a regular *entailed* estate, to descend to successive generations. It is probable that our knowledge of the seeming anomalies of this species, which is now very imperfect, may receive valuable accessions from the greater attention which has of late been bestowed on these lowly tribes.

All the annelids yet mentioned are of a very elongated form; but there are others that are oval. One genus of these bears the name *Aphrodita.* Along the back are two rows of membranous scales (Fig. 54), and underneath these are the gills. All the body is covered with delicate, silky hairs, from which circumstance the common English name of "Sea-mouse" has probably originated. At the sides are little *setæ*, or bristles (Fig. 54), which are, to a certain extent, retractile. These hairs are of a remarkable structure, being in some species barbed on each side, as in *Aphrodita hispida* (Fig. 54), thus, in point of fact, forming perfect harpoons. Such weapons, when erected against an assailant, would obviously be more formidable than "quills upon the back o' the fretful porcupine."

But it needs "no ghost to come from the grave to tell us" that if such instruments were drawn back into the body, the animal itself would be the first to suffer from its own harpoons. This danger is averted by a very simple and beautiful contrivance. Each of the barbed spines is furnished with a smooth horny sheath, composed of two blades; these close on the spines when drawn inwards, and most effectually protect the flesh from injury (Fig. 54).

The most obvious character of the hairs of the Sea-mouse is not, however, that which has just been mentioned, but the play of rainbow colours over their surface. The metallic effulgence of copper ores, the wings of tropical insects, the breasts of the brightest humming-birds, are objects called to mind by this beautiful iridescence. Often, however, it has been my lot to bring up the Sea-mouse in the dredge, surrounded by a mass of black mud; and of course at such times this gorgeous embellishment of colour was wanting, or rather, it was hidden. Cinderella employed at menial work in the house of her step-mother, and Cinderella dancing with the prince in the ball-room, were not more different than the Aphrodita when thus captured, and the same when it had undergone the needful ablutions, and been transferred to a phial of pure sea-water.

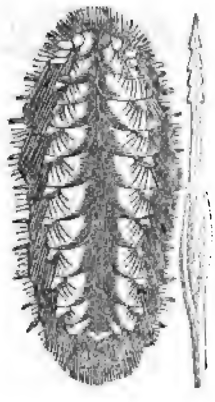

Fig. 54.

And now, reader, we approach another resting-place. We have visited the four orders of annelids, and marked their modes of life. We found that one of them was known as "suctorial," another as "terricolous," a third as "tubicolous," and a fourth as "wanderers;" or dropping these terms, and taking certain species as the representatives of the rest, the orders are typified by the Leech, the Earth-worm, the Serpula, and the Aphrodite. These four orders constitute the class ANNELLATA, the first group of the Articulated division of the animal kingdom. Yet, though our theme has been a lowly one, I must, ere quitting it, observe that there are traditionary errors with regard to some worms, which, even in these days of boasted enlightenment,

are still current, and will continue to be so until natural history be made a regular part of elementary instruction in every school-room, whether for rich or poor. As an example may be mentioned the hair-worm (*Gordius aquaticus*), a species abundant, during the summer months, in many rivulets. It is usually eight or ten inches long, and the common superstition about it is, that horse-hairs placed in water become vivified, and are changed into those worms. This notion—with the addition that the hair-worm was the young state of serpents—was prevalent in the days of good Queen Bess, and has thus been recorded by the immortal Shakespeare:—

> "Much is breeding,
> Which, like the courser's hair, hath yet but life,
> And not a serpent's poison."

CHAPTER XVI.

Class Cirripeda.

BARNACLES AND ACORN-SHELLS.

> *Caliban.* "We shall lose our time,
> And all be turned to *barnacles*."—*Tempest*, Act IV., sc. 1.

While we read the scene in which the above passage occurs, our minds are so occupied with Stephano, Trinculo, Caliban, and the "delicate Ariel," that we pause not to ask, "What are barnacles?" Or if some one, less enchanted and more inquisitive than others, should wish to know, and should turn to the foot-notes for information, he may find, as I have done, that "the barnacle is a kind of shell-fish, growing on the bottoms of ships." If he seek to know more than this, and apply to the naturalist, he may be surprised to hear that barnacles are not shell-fish, in the sense in which the term is applied to limpets or oysters, and that their organization is so different, that they even belong to another class, being included in the *Articulata*, or jointed animals, instead of the *Mollusca*, or soft-bodied, and are, in point of fact, very closely allied to the *Crustacea*.

Their shells resemble so much those of molluscs, that at a time when the structure and habits of the contained animals were imperfectly known, it was not unnatural that they should be regarded as *Multivalve* shells, and classed accordingly. Some are attached to floating pieces of timber, or to the bottom of vessels, by long peduncles or foot-stalks, such as are shown in the figure 55. Others are firmly attached by their calcareous base to rocks, shells, or other objects. The body of the pedunculated species is soft, and enveloped in a membrane. "It is provided with six pairs of rudimentary feet, jointed and terminated each by a pair of long, slender, many-jointed tentacles, curled towards the mouth, and thence giving origin to the name of the class, *Cirripeda*, curl-footed."

These, by their movement in the water, occasion currents, which bring food to the mouth, and a fresh supply of aërated water to the gills. It is not unlikely that their feathery appearance may have suggested the idea that

they are the embryo condition of the Barnacle-goose! The specific name *Anatifera*, or goose-bearing, applied to the most common species of *Lepas*, records what was at one time the general belief.

This remarkable tradition is still current among the uneducated, and deserves more than a passing notice, as an example of the senses being led captive by the imagination. We find in one of our earliest prose works, the *Voiage and Travaile* of Sir John Maundeville, written five hundred years ago, a reference to it, as to a strange but undoubted fact, and one which was a sufficient warrant for his giving credence to a tale not less marvellous, of young lambs being produced by a fruit-bearing tree! The passage is worth quoting, as an instructive example of the strange things to which men have assented, even in a department of science which ought to be based on correct observation:—

Fig. 55.

"In pasynge be the Lond of Cathaye toward the highe Ynde, and toward Bacharye, men passen be a Kyngdom that men clepen Caldilhe: that is, a fulle fair contree. And there growethe a manner of Fruyt, as thoughe it weren Gowrdes; and whan thei ben rype, men kutten hem a to, and men fynden withinne, a lytelle Best, in Flessche, in Bon and Blode, as though it were a lytylle Lomb, with outen wolle. And men eten bothe the Frut, and the Best: and that is a gret Marveylle. Of that Frut I have eten; alle thoughe it were wondirfulle: but that I knowe wel, that God is marveyllous in his werkes. And natheless I tolde hem, of als gret a marveylle to hem, that is amonges us: and that was of the Bernakes. For I tolde hem, that in our contree weren Trees, that beren a Fruyt, that becomen Briddes fleeynge: and tho that fellen in the water, lyven: and thei that fallen on the Erthe, dyen anon: and the ben right gode to Mannes mete. And here of had thei gret marvaylle that sume of him trowed, it were an impossible thing to be."

From this it would appear that some of Sir John's auditors were rather incredulous about the truth of his "marveylle." Such was not the case with Gerarde, the author of a *Herbal, or General History of Plants*, published in 1597, and long regarded as a botanical authority. "There are found," says he, "in the north parts of Scotland, and the islands adjacent, called Orchades, certain trees, whereon do grow certain shells of a white colour, tending to russet, wherein are contained little living creatures, which shells in time of maturity do open, and out of them grow those little living things, which, falling into the water, do become fowls, which we call Barnacles; in the north of England Brant-geese, and in Lancashire Tree-geese; and

the other that do fall upon the land, perish and come to nothing. Thus much by the writings of others, and also from the mouth of people of those parts, which may very well accord with truth.

"But what our eyes have seen and our hands have touched we shall declare. There is a small island in Lancashire, called the Pile of Foulders, wherein are found the broken pieces of old bruised ships, some whereof have been cast thither by shipwreck, and also the trunks and bodies, with the branches of old and rotten trees cast up there likewise, whereon is found a certain spume or froth that, in time, breedeth unto certain shells, in shape like those of a mussel, but sharper pointed and of a whitish colour, wherein is contained a thing in form like a lace of silk, finely woven, as it were, together, of a whitish colour, one end whereof is fastened unto the inside of the shell, even as the fish of oysters and mussels are; the other end is made fast unto the belly, of a rude mass or lump, which in time cometh to the shape and form of a bird; when it is perfectly formed, the shell gapeth open, and the first thing that appeareth is the foresaid lace or sting; next come the legs of the bird hanging out, and, as it groweth greater, it openeth the shell by degrees, till at length it is all come forth, and hanging only by the bill. In short space it cometh to full maturity and falleth into the sea, where it gathereth feathers, and groweth to a fowl bigger than a mallard, and lesser than a goose, having black legs and a bill or beak, and feathers black and white, spotted in such manner as our magpie, called in some places a pie annet, which the people of Lancashire call by no other name than a tree goose; which place aforesaid, and all those parts adjacent, do so much abound therewith, that one of the best may be bought for threepence. For the truth hereof, if any doubt, may it please them to repair unto me, and I shall satisfy them by the testimony of credible witnesses."

Of the real changes which these animals undergo nothing was known until, in 1826, Mr. J. V. Thompson captured in a small towing-net a number of minute translucent creatures, about the tenth of an inch in length, and of a somewhat brownish tint. The annexed figure (Fig. 56) gives an enlarged representation of their appearance. After a few days they threw off their outer skin, attached themselves firmly to the bottom of the vessel, and soon assumed the appearance of the sessile barnacles or acorn-shells (*Balanus pusillus*).

Fig. 56.

The pedunculated barnacles present in their young state an appearance very unlike the others (Fig 57); but the changes they undergo in passing from their free to their adhesive state are, in all essential points, precisely similar.

In a number of the *Annals and Magazine of Natural History* (Oct., 1851), there is a very able paper, by Mr. C. Spence Bate, on the development of these animals, illustrated by numerous figures, from which it would appear that the larva undergoes a series of metamorphoses in passing from the young to the adult state; and that the eyes, which are absent in the very young *Balanus*, become fully developed in a further state of advancement.

Perhaps there is nothing in the whole series of changes which strikes the contemplative mind more strongly than the beneficent, yet economical, pro-

vision regarding the organs of sight. They are given when the animal is free and locomotive, and when we may suppose the sense of sight to be essential to its welfare. But so soon as it has chosen its "place of rest," and becomes fixed for the remainder of its existence, a calcareous deposit takes place, and the eye, no longer wanted, is obliterated for ever.

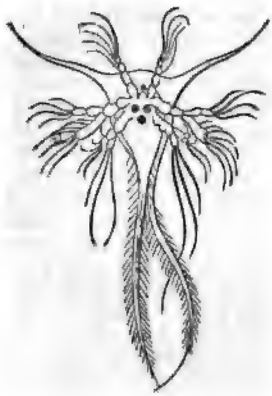

Fig. 57.

The fact of the *Cirripeda* being met with in all seas, and some species found uniformly attached to certain bodies and to them only, might naturally have suggested the idea that they must in their young state have had the power of moving freely about, and also of selecting the site of their future dwelling. But nothing positive was known until 1826, as already mentioned.

The bodies to which they are attached are not always inanimate, like shells, stones, vessels, and floating timber. Some are affixed to or buried in corals; one performs its voyages on the backs of turtles, and another (*Coronula balænaris*) selects a still stranger abode, being imbedded in the skin and fat of whales.

Some of the larger kinds are used as food. The Chinese eat the soft parts of one species (*Balanus tintinnabulum*), which has the reputation of being like the flesh of a lobster when boiled. Captain King tells us of a South American species (*Balanus psittacus*), found at Conception, which is frequently five and a half inches long, and three and a half inches broad, and occurs in large bunches, which are chopped off with hatchets. They are exported in quantities to Valparaiso and Santiago, where they are much prized, for the flesh equals in richness and delicacy that of the crab, which, when boiled and eaten cold, it very much resembles.

But we must leave China and South America, and return to our own shores; and as I wish all my young readers to observe and to experiment for themselves, I do not know that I can conclude the present chapter better than by the following paragraph from Patterson's *Zoology for Schools*:—

Fig. 58.

"The cheapness of the pleasures which natural history affords should of itself form a reason for their general cultivation; for they are within the reach of all. By means so simple as a glass of sea-water we have caused the Balani, or Acorn-shells, to exhibit a series of movements, which we have never shown to the youth of either sex without hearing from them expressions of the most unfeigned delight. Let the reader try the experiment. Go at low water to a rocky part of the beach; choose a few of the oldest and largest limpets left uncovered by the receding tide, and incrusted with the acorn-shells. As the inclosed animals then have been without nourishment for two or three hours, they will be quite ready for another meal. Throw the limpet-shells

into the glass of sea-water, and in a minute or two the acorn-shells upon them begin to open. Presently a beautiful feathered apparatus will be extended, then withdrawn (Fig. 58). It will again be put forth, and again retracted; but with such grace, regularity, and precision, that the eye regards it with ever new delight. And when the same exquisite mechanism is exhibited by every one of them, either in succession or simultaneously, and when we consider that it thus ministers at the same moment both to respiration and nutrition, a train of ideas is excited, which rises from the humble shell to Him by whom it has thus wondrously been fashioned."

CHAPTER XVII.

Class Crustacea.

CRABS, LOBSTERS, ETC.

> "By paved fountain, or by rushy brook,
> Or on the beached margin of the sea."—Shakespeare.

The essential characteristics of the Crustacea are the combination of gills or branchiæ for respiration, with jointed limbs and distinct sexes. The name is derived from the external covering, which is less solid than that of testaceous molluscs generally, but harder and firmer than the skin of naked molluscs. It is, in fact, perfectly capable of rendering to the animal all that it requires, namely, protection from the violent concussions to which it is subject among the rocks which are its dwelling-place, and from the attacks of enemies—and a point of support for the limbs in their efforts at locomotion. In the crab and lobster the integument is harder than in many of the smaller species, through the addition of earthy particles of carbonate and phosphate of lime. The colours of the shell are owing to a pigmentary matter of a peculiar nature. This changes to red in a great number of species when subjected to alcohol, ether, acids, or to boiling water; the last being the process to which the eatable Crustacea are, as is well known, exposed. The skeleton, or framework of the integument, is composed of a series of rings, the original number of which appears, from the segments of the animal's body, to be twenty-one. The head, the thorax, and the abdomen generally, comprise each seven of these rings. The skeleton as a whole is broadly divided into two parts—the anterior or carapace, a sort of buckler, covering the head and thorax; and the posterior, including the abdomen.

One of the first things that strikes us in looking at a fully-formed, hard integument of this kind is the impossibility of the animal's growing in such a case of mail. How does Nature meet this difficulty? Why, by moulting. The canary does not more regularly cast its feathers than the Crustacea rid themselves of their house or stronghold. The frequency with which this is done is truly surprising. A young daphnia has been observed to cast its shell eight times in the space of seventeen days. We may take the craw-

fish as an example of the mode. This animal about the end of the summer ceases to eat, shows signs of sickness, and presently the carapace becomes loosened from the corium, or part to which it was attached. At the same time a secretion is poured forth, which is at first soft, like a membrane, but gradually hardens into a shell. When the new house is complete, the old one, of course, becomes little better than a nuisance, and must be got rid of. So the uneasy animal begins to rub its legs against one another, then to turn on its back and shake itself, then swell until it rends the membrane which still connects the old carapace with the abdomen. But this is hard work, and somewhat painful also, no doubt. So the craw-fish rests awhile. But again its labours must recommence; the carapace must be thrown off—head, eyes, and antennæ must all be freed; and when these things are accomplished, there remains the most difficult part of the task—the extraction of the extremities. This is aided by the splitting of the integument the whole way along, from end to end; but, after all, the poor animal is obliged not unfrequently to leave a limb or two behind. Sometimes, indeed, it cannot extricate itself, and perishes. The abdomen is the last portion freed. And so, generally, in about half an hour is the moulting accomplished. Very tender is the new integument at first, and very timid, consequently, its owner.

It may seem a somewhat alarming feature of the moulting, this liability to lose a limb or two in the doing it. But the animal evidently has no very high notions of the value of any particular one or two of these appendages, for it will throw them off, when sudden injury or offence happens to them, almost as heedlessly as we should throw off a glove that had been accidentally contaminated. The land-crabs that used to be found in the garden of the Zoological Society presented a laughable example of this levity in the treatment of one's limbs. If any of these were taken up by the smaller legs in a manner which incommoded them, they cut the connection at once, and ran off upon the remaining members, apparently as contented as before. The meaning of all this is, that the cunning animal knows it can reproduce any reasonable number of legs at will. All it has to mind is, that the division takes place at a proper point, near the basis of the limb, which then speedily heals over, and presently puts forth a new claw, at first small, but which grows gradually to the proper size. If the division does not take place at a right point, bleeding goes on, and would prove fatal, but the animal then, by a great effort (apparently a violent muscular contraction), shakes off the part that remains beyond the spot where the division should have taken place.

The forms of the Crustacea are strange and fantastic, and the uses to which portions of the frame are put still more extraordinary. We find legs officiating not only in the capacity of locomotive support, but as jaws wherewith to masticate food, or as gills to promote the business of breathing. Some have the carapace greatly developed, as in the walking Crustacea; while others, of which the swimming Crustacea may be taken as examples, have the abdomen of large (relative) dimensions. In fact, this part is the principal agent of locomotion in the water. When the animal wishes to progress, it is by bending the abdomen suddenly downwards under the sternum that it strikes the water, and consequently, by darting backward, that the animal makes its way through the liquid.

It is necessary here that we should briefly classify the numerous species

comprised within the great Crustacean family. The chief division is suggested by the fact that some have jaws for masticating food, while others have merely a kind of beak, or tubular apparatus, through which they draw their food by suction; and there is yet a third class, whose mouth is surrounded by legs, the bases of which are used as jaws. All Crustacea are therefore divided into the Maxillosa, or masticating; the Edentata, or Hausstellata, the suctorial; and the Xiphosura, or the sword-tailed. The masticating and the suctorial, again, are each divided into various great sections, with further subdivisions into orders and species.

The most interesting feature of the masticating Crustacea is the jaw-foot, represented in the following cut. In the sucking Crustacea, which are parasites, and feed on other animals, we have, instead of the jaw-feet, a tube, or proboscis, containing within a pair of animal-lancets. These make the wound through which the juices are afterwards drawn. The food, thus prepared, passes through a short tongueless mouth into the œsophagus, thence into the stomach, where we find an extraordinary apparatus for tearing and grinding the food, consisting of tubercles, or teeth. The liver is largely developed in many Crustacea, especially in the decapods, or ten-footed, as every epicure in shell-fish well knows, for in this order are included lobsters, crabs, and shrimps. The blood is either colourless, or of a slightly bluish tinge, and is circulated, it is believed, in a similar manner to that of the molluscs. The heart is single, and of various forms—square, cylindrical, &c. The appearances presented by the heart in some Crustacea have been likened to the effect produced by the superposition of a number of stars, the rays of which do not correspond.

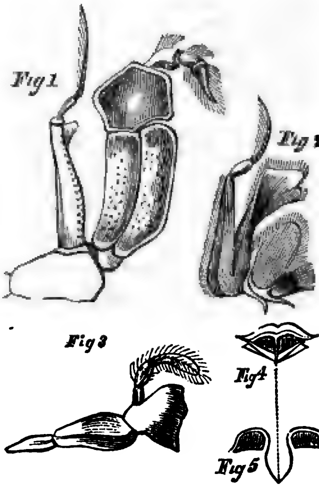

Fig. 59.—JAW-FEET OF THELPHUSA FLUVIATILIS.*

The respiratory process in the Crustacea is a very interesting and very complex subject. Generally, breathing takes place through the branchiæ, or gills—an organ familiar to all eaters of the crab, in the form of a number of leaf-like processes, arranged in two groups, the points coming nearly together. In some Crustacea no special respiratory apparatus can be discovered, and oxygen is then supposed to be drawn directly through the external integument. In others, the gills float in the water, like so many feathery tufts. The Phyllopoda, or *gill-footed*, are distinguished by an extension of their legs, in order to make the latter subservient to respiration —a fact which explains the movement sometimes seen in the feet of such animals, when all the rest of the body is quiescent. The land-crabs possess

* 1. Right external jaw-foot; A, its internal blade; *a*, *b*, *c*, *d*, *e*, *f*, its various articulations; B, its external blade, or palp. 2. Jaw of the third pair, with its palp. 3. Mandible, with its palp. 4. Upper lip. 5. Lower lip, sometimes called the tongue.

special contrivances for the moisture requisite to enable the gills to perform their functions. For the same reason these animals never go far away from damp situations. With them the activity of the breathing organs is so great that they cannot draw the requisite supply of oxygen from water, and consequently they die, if long immersed. We may fitly illustrate the foregoing remarks by the annexed engraving, showing the circulatory and respiratory system of the lobster.

Fig. 60.*

There is no brain, strictly speaking, in Crustacea, but there is a tendency towards its formation visible in the centralization of the nervous functions in the anterior part of the ganglionic chain. The place of the brain in the higher animals is occupied, in Crustacea, by the ganglions, which possess individually the faculty of receiving sensations and determining motion, and which act through the nervous cords.

The eyes of Crustacea exhibit a great variety of structure. In certain classes we find smooth, or simple eyes, two or three in number, formed by a mere modification of the tegumentary membrane, with a mass of gelatine behind it, acting as the vitreous humour, and which is in connection with the optic nerve. The king-crab is an example. These simple eyes, or *stemmata*, are always immovable, and *sessile*, or sitting. Other classes have what are called intermediate eyes, in which the cornea is still undivided externally, but has behind a number of simple eyes, or lenses, each with its own vitreous humour, and its own connection with the optic nerve. Lastly, (and this refers to the great majority of Crustacea,) we have compound eyes, presenting a number of facets, each with its own ocular compartment behind. These facets are square in the common craw-fish, hexagonal in the crab, and so on. There is a remarkable fossil species, in which there are four hundred of these facets, the whole so exquisitely arranged for mutual aid, that where the range of one ceases, that of the next begins. There are generally two of these compound eyes, although sometimes they are so closely united as to appear but as one. Sometimes the compound eyes are movable, and sometimes they are supported on a pedicle, or stalk, moved by special muscles.

* *h*, Heart; *s*, sinus, or dilated vein, receiving the blood which comes from different parts of the body, and is thence sent to the branchiæ, *b*, from whence it returns to the heart by the branchial veins, *v*.

[END OF ZOOLOGY.]

PART IV.

THE

PHYSICAL HISTORY OF MANKIND.

THE PHYSICAL HISTORY OF MANKIND.

CHAPTER I.

INTRODUCTORY.—ON THE OBJECTS AND INTEREST OF THE STUDY OF MAN.

As a motto to this division of our "Home Tutor" we might most appropriately adopt the line of the poet—

"The proper study of mankind is man."

We do not, however, wish it to be inferred that our own subject is above all others that which ought peculiarly to interest mankind. In fact, the expression of the poet is rather an assertion of what is, than what ought to be. There are many reasons why man should be, to himself, the most interesting and absorbing of all studies. Surrounded by an external creation constantly suggestive of thoughts of the beautiful, the grand, and the sublime, man yet turns his mind upon himself, and finds that it is in his own wonderful nature that he must look for the true source of the beauty and the wonder of the external world. The heavens and the earth are alike unfolded to the eye of lower beings; but they kindle no emotions in their consciousness, and add no happiness through thought to their being.

The thought and consciousness of man, his soul and understanding, have ever been to him a theme of intensest interest, and must, whilst the human race continues on the earth, occupy a first place in his regards. Setting aside the thought by which man is enabled to reason and study as a part of his nature, his relation to the rest of creation must give him a deep interest in his race. When we regard the external world with attention, we see clearly that the distinction between the material world and that of organic existences is very great. However wonderful may be the movements of the heavenly bodies, and the grand features which mark the physical geography of the surface of the earth, we instinctively feel that there are higher agencies and a more mysterious power at work in the growth and functions of the simplest plant of the field. We speak of rivers, seas, rocks, and mountains as existing, but of plants as living. We feel that there is more proof of Wisdom and Goodness in the creation of a plant than of a stone. We then pass on from plants to animals, and we observe in passing up from class to class, till we arrive at the highest, the gradual complication of their structure, the increase of their functions, the numerous new relations they sustain to the mineral and vegetable world, and we feel that animals are more wonderful structures than plants, and they accordingly take a stronger hold of our sympathies, and demand a larger part in our affections. If then we carry on our view to man, and find him embracing all that is wonderful in the creations below him, and exhibiting new and unlooked-for adaptations to his position in the world, we shall see how it is that man, as an object external to himself, becomes one of the most interesting and absorbing subjects of his own study.

Our object, however, in these papers, is not to speak of man generally, but in a particular point of view. The study of the frame of man constitutes the science of human anatomy; the functions it performs, that of physiology. The laws which regulate the exercise of his mind and feelings constitute the field of inquiry for the metaphysician; and the actions of man, as they originate in moral causes in nations and communities, constitute the science of history. But, independent of all these, we find that the relation of man to the rest of creation—the effects of physical causes upon his habits and manners—the varieties of structure and appearance which he presents on the surface of the earth—and, in fact, all that relates to his external physical character, constitute a subject of deep interest, and one that is at the present moment engrossing a greater amount of attention than it has ever before done in the history of the world. The causes of this attention are numerous and interesting, as showing what are the questions involved in this subject. To a few of these we shall allude.

In the first place, we may make the assertion that there is more than one species of man inhabiting the earth. We shall have presently to examine this question, and we refer to it here as showing the ground which our subject will take us over. The unity or multiplicity of the human species is one of great interest, and also of importance. The supposed multiplicity has been adopted as an argument against the truth of the doctrines of Christianity; and the alleged specific distinctions between the Negro and the Anglo-Saxon have been employed to justify the condition of slavery which the latter race, in America, has succeeded in forcing on the former.

The great increase in our knowledge of the races of men, through travellers and missionaries, has very much contributed to increase the interest in this subject. Travellers have also gone out prepared to make the necessary inquiries, and have had their attention directed to those points which could throw light on some of the interesting problems to be solved in the physical history of man. The spread of the missionary spirit in Great Britain, during the last fifty years, has contributed a vast mass of useful materials from all the countries which have been visited by the preachers of the Gospel. The materials thus collected have been collated, and an increased interest given to the history of tribes and races in various parts of the world.

Nor should we omit to mention the increase of our colonial empire. Every day is bringing our soldiers and sailors into more close contact with people whose names, only a few years ago, were unknown among us. In the narratives of voyages, settlements, expeditions, and governorships, we have had lately constantly introduced to us new races, with new habits and languages; and thus has increased the stock of information, as well as our interest about the physical history of man.

The question of race, however, is not confined to distant parts of the world. In various parts of America we see the red, the black, and the white man living in the same communities. Although in Europe we have no large part of the population either red or black, yet we have distinctive races. The Celtic Irish, the Saxon English, and the Hebrew are familiar enough to ourselves; and the distinction of Saxon, Celt, and Jew is seen as prominently on the continent of Europe. Further distinctions exist there, as we shall see, and the study of these distinctions has gained a deep interest in these days, as it is the opinion of many, who have studied these subjects gravely, that the late revolutions on the continent have been more the result

of difference of race than any other cause. On this ground, at least, we may explain some of the more striking events of the last few years, and the increased interest which has been taken in our subject.

Again, the application of the study of languages, as a means of ascertaining the relation of races, and the success which has attended these researches, have contributed much to increase the interest taken in the physical history of man, as well as to direct towards this subject the minds of a number of intelligent men, between whose pursuits and those of the naturalist and the natural philosopher it acts as a bond of union, and a mutual ground of research.

Lastly, we may mention emigration. Large numbers of our countrymen are every year seeking homes in untried lands, and amongst different races of people, and the desire of knowing something more of the latter has prompted the perusal of works on the Natural History of Man. Besides this, another question of interest arises to the European emigrant, and that is—In what climates, and under what circumstances, can his race expect to succeed, and carry on the great objects of existence?

These are some of the circumstances which have lately tended to give an impulse to the study of the physical history of mankind, and it will be seen, from these introductory remarks, that, independent of its special interest as a study, important practical consequences result from a knowledge of the physical conditions which influence the races of men.

CHAPTER II.

THE PHYSICAL PROPERTIES OF MAN'S BODY; STRUCTURE OF HUMAN SKELETON, AS COMPARED WITH LOWER ANIMALS.

In order to understand the nature of the influence which climate, soil, locality, and other circumstances exercise upon the external appearance and structure of man, we shall make a few general observations upon his relation to the external world. When, with the assistance of the chemist, we examine the matter of which the human body is composed, we find it to consist of the same kind of elements as those which are found in the lower animals, in plants, and in minerals. The human body obtains these particles of matter through its food. This food is mainly derived from vegetable substances. On examining plants, to ascertain how they obtain the elements of which their structure consists, we find they derive them directly from the mineral kingdom. If we analyze a portion of human flesh, we shall discover it to consist principally of four elements—carbon, hydrogen, nitrogen, and oxygen. These also form the chief part of plants. Hence they have been called *organic* elements. In addition to these, man contains in his body several other substances. His bones contain earthy as well as animal matter. The mineral which forms part of the bones is called phosphate of lime. It is found in the waters of the ocean, and also occasionally in a crystalline form on the surface of the earth. In analyzing the blood and the soft fleshy parts of the human body, the chemist finds many other mineral constituents, and these not accidental, but constant. Amongst

these we may mention lime, magnesia, potash, soda, and sulphuric, phosphoric, nitric, and acetic acids.

From these facts, then, we may arrive at two very important conclusions with regard to the physical structure of man. First, that the materials of which the fabric of his body is composed obey the same laws as those obeyed by the inorganic matter by which he is surrounded; and secondly, that the elements of which his body is ultimately formed are identical with those which are found in the mineral world.

In accordance with the first of these facts, we find that the body of man obeys the law of gravitation, and that he maintains his position on the surface of the earth in virtue of this law. To this law we find much of his physical structure obedient. He is intended to maintain the erect position, and the muscles of the back, head, and legs, by which this is effected, are nicely adapted, in their strength and the direction of their power, to resist the action of this law in drawing the whole body to the ground. The same adaptation of muscular power to the resistance of the law of gravitation is observed in the lower animals. The sustained flight of the bird, by which its body is kept frequently for so long a time passing through the air above the surface of the earth, is effected by means of muscles endowed with the necessary amount of power to secure this object. In the insect world we see marvellous instances of strength given to special muscles, in order to resist the attraction of the matter of the insect's body to the earth on which it dwells. The wings of the common fly, and the legs of the flea, may be given as examples of this power.

It is not merely the law of gravitation that the body of man obeys, but whatever may be the laws which govern matter in a state of rest or motion, whether solid, liquid, or aëriform, the body of man, as a mass of matter in a solid, liquid, and gaseous form, is found to be subservient to them. Many are the laws of statics, mechanics, hydrostatics, hydraulics, and pneumatics which find illustration in the structure of the human body. We must, therefore, be prepared, in our studies of the physical history of man, to discover that the laws which govern matter, independent of all chemical or vital change, have great influence on his condition and habits.

The elements of man's body being identical with elements found in the material world, we must also be prepared to find that man's dependence on the external world for the supply of certain elements which are necessary to the composition of his mere animal fabric, has had an important influence on his physical condition. Human chemistry has not advanced so far as to point out what are the chemical constituents which characterize particular races of men; but we know enough of human physiology to be able to perceive that many of the functions of life are carried on by means of chemical changes, which are produced amongst the elements of which the body is composed.

To give a few illustrations of this position, we may refer to some well-known facts. Thus common salt—which is a compound of chlorine and sodium—is essential to the health of the human body. In all civilized countries it is extracted from the earth or the ocean, and added artificially to the food of man. An increased or diminished supply of such an element could not fail to produce important modifications in the system, when acting through a long period of time. The absence of iron in the blood, it is well known, produces certain changes in the system, which are most obviously

impressed on the physical appearance of the white races of men. This substance, in certain quantities, is needed in the food of man all over the world to produce a healthy life; and it is only reasonable to conclude that its constant deficiency or redundance would produce permanent physical effects. We need not here refer, at any greater length, to the chemical composition of the frame of man; but we would observe that it confirms, in the most accurate manner, the account of the creation of man which is given to us in the Bible. It is there stated that God formed man from the "dust of the ground," and we find in the material constituents of his frame the same elementary bodies that are found on the earth's surface. It is true that a large proportion of man's body is composed of water, and the gases oxygen, hydrogen, and nitrogen; but taking "the dust of the ground" as an expression intended to indicate the mineral and inorganic nature of the materials of which man's body is formed, we cannot but regard the discoveries of modern science as in accordance with the spirit of this remarkable record of the creation of our race.

In the physical properties of the components of his body to which we have here referred, man has a community of character with the lower animals. There is, however, a striking difference between the relative quantities of the chemical elements in different animals—a difference, in many instances, connected with their peculiar structure, and which, as it supplies an instance of the manner in which physical qualities alter the appearance of animals, will afford an illustration of our previous remarks. In the human system we find very little carbonate of lime deposited in any part of it. This substance, which, as a mineral, assumes the forms of chalk, marble, and limestone, is, however, found in the human body in small quantities. But if we examine the class of animals called Mollusca, to which the various forms of land shells and shell-fishes belong, we shall find that the whole of their shell is composed of carbonate of lime. This substance is soluble in water containing carbonic acid gas; and thus we find it in solution in seas, rivers, and springs, and the creatures inhabiting these waters are able to separate it from its dissolving acid, and to form for themselves an insoluble tenement to dwell in. The form of the shell is the most obvious character of the whole of the mollusca, and this form is derived from the carbonate of lime, and none of the shell-forming mollusca could exist without it. In this case we have a beautiful instance of the peculiar chemical properties of a substance determining the characters of a whole family of animals. Let us add another instance. It is a well-known fact that the fishes of fresh waters differ in their characters from those of the sea. They will not live in salt water, nor will the fishes of the sea live in the fresh water. Chemistry reveals to us the fact, which our sense of taste would suggest, that the fishes of the sea contain certain ingredients which they derive from sea plants and sea water, which they cannot obtain in fresh water, and which are necessary to their peculiar form and existence. We might extend this observation, and show that the fishes of brackish water differ from those of fresh water on the one hand, and those of sea water on the other. Not only is this the case with fishes, but the whole of the animals and plants of the ocean differ from those found in fresh waters; and the differences, observable in a thousand various forms, seem all determined by the presence of common salt, and other saline matters, in the sea.

But, whatever community there may be between man and the lower animals in the identity of their physical composition, in his animal structure man holds a much higher position than any of the class of beings to which he belongs. This position he holds more in virtue of the greater complication of his structure than in the functions (excepting his mental qualifications) which he performs. If we descend to the lowest animals, we find them taking food, digesting it in a stomach, preparing it for the use of the body, and procuring animal heat from it by a process of respiration. The nutritious matter thus prepared is worked into the fabric of the body, is consumed in the performance of the various functions, and is afterwards thrown off from the body. This process goes on for a period—the animal produces creatures like itself, and at last dies. These are the processes which go on in the human body; but the organs by which they are performed in man are very much more complicated, and subservient to much higher powers of mind, than are found in any of the lower animals.

In order to show the more complicated structure of man, we need not refer to the lowest animals, but compare him with those highest forms which are allowed by all naturalists to come nearest to him in structure and general resemblance. The highest class of animals amongst those which are called vertebrate, because they possess a back-bone, are the Mammalia. This class of animals is known by many peculiarities ; but that which distinguishes them most, and has given them a name, is the fact that their young are born alive, and are nourished for some period after their birth by food supplied by suckling from the mother. This class is divided into several orders, according to the development of the extremities and the teeth. The higher the animal is in organization, the more divided and sensitive become its extremities, and the more various in form its teeth. The ruminants, to which the ox and the sheep belong; and the pachyderms, to which the horse and the elephant belong, are, on account of their hoofed feet, and the deficiency of some forms of teeth, placed lower than the carnivora and quadrumana, in which the feet are divided into fingers and claws, and the teeth consist of the three principal forms, viz., grinders, canines, and incisors.

If we now regard the point of sensitiveness in the toes and fingers as indicating a higher range of adaptations, and requiring a larger development of mental capacity, we shall at once see the quadrumana—the order which includes the apes, baboons, and monkeys—must be placed in a position superior to that of the carnivora, the order to which the lion, the tiger, the dog, and the cat belong. With the superior development of the fingers and toes in the quadrumana, we find, amongst many of the tribe, a great advance from the carnivora and other lower tribes towards the structure of man. Many of the monkeys possess considerable manual dexterity : their body approaches the erect position, the structure of the skull gives to their face a more human appearance, and their general intelligence is greater than that of any other animals. But if we now compare man with even these highest creatures, we shall see that his structure is more complicated, and that, in a vast number of points, he not only differs from these creatures, but affords proof of a great advance in all that indicates a higher and superior development of animal structure.

Compare the two figures (1 and 2), and every one will feel instinctively, at a glance, the superior beauty and higher development of the skeleton of

an as compared with that of the orang-outang. The first thing that strikes the observer is the manifest want of adaptability in the skeleton of the baboon to maintain the erect position; whilst the placing of man on his hands and feet is felt to be opposed to his structure. If we examine the two skeletons from this point of view, we shall observe a number of remarkable structural differences. In the first place, it will be seen that the feet of man are broader than those of the monkey, and of any other animal in proportion to its size, in order to give a surface large enough for the body to be conveniently placed on them, and moved with rapidity. On examining the bones of the tarsus (instep), (Figs. 1 and 2, *n*), it will be seen that they are bound firmly together, and that they are on a level with the bones of the toes. This is not the case with the orang, in which the bones of the tarsus are loose, and considerably elevated above those of the toes. In dogs, and many other quadrupeds, the bones of the instep and wrist are considerably elevated from the ground, and the body rests entirely on the toes. In the horse, and other animals with a solid hoof, not only are the bones which represent the wrist and instep in man elevated, but only the third series of bones constituting the toes (Fig 1, *o*) rest on the ground. The whole structure of the foot of man is adapted to sustaining the weight of the body, and is not used for the purposes of prehension, as is the case in all the quadrumana. In this we have an instance of higher development, as the function of handling, which is possessed by both the fore and hind extremities of the monkeys, is entirely confined to the upper in man. Whilst the function of supporting the body, which must necessarily interfere with the delicate sensation required for expert manipulation, is performed by all the extremities of the monkeys, it is confined to the lower extremities in man. It is this

Fig. 1.

fact that at once constitutes man "bi-manus" and "biped"—a combination not found in any other animal.

If we now cast our eyes above the foot, we shall see how differently the parts of the leg are placed in relation to it in man and the monkey. In the former the tibia and fibula (Fig. 1, *m*) are placed at right angles with the foot, and the heel-bone projects so as to receive the tendon of the powerful muscle which constitutes the calf of the leg, and performs the most service in the locomotion of the body. Above the bones of the leg are those of the thigh (Figs. 1 and 2, *l*). On these bones the broad pelvis of the man (Fig. 1, *i*) rests, and, by the peculiar shape of the neck of the thigh-bone, a broad surface of support is secured. In man the bones of the thigh are much longer than in the orang, and wider apart in proportion to their length at the summits. The pelvis (Fig. 1, *i*) in man differs remarkably from that of the lower animals; it is much broader and firmer at the back, in that portion on which the bones of the spine (Figs. 1 and 2, *g*) rest. The bones of the pelvis are also much curved below, for the support of the internal viscera, and also to render the sitting posture of man tolerable, which would be impossible were this part of his skeleton constructed on the same principle as that of the orang-outang.

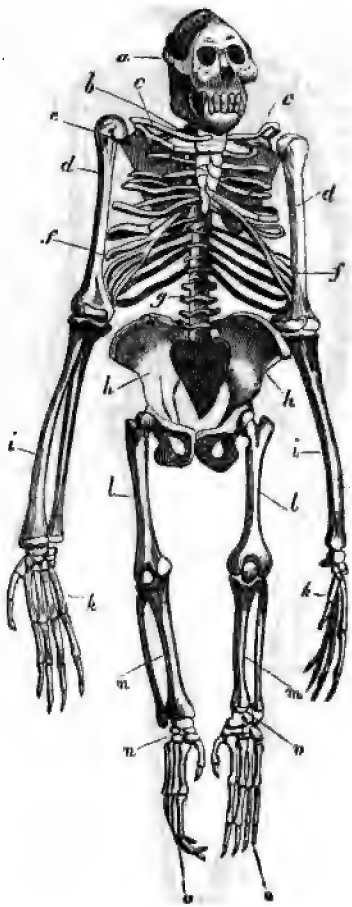

Fig. 2.

From the pelvis we pass to the spine, that part of the skeleton included between the head and the pelvis, and which is composed of a number of small bones called *vertebræ* (from *vertere*, to turn). These are divided into three kinds—the lumbar (Figs. 1 and 2, *g*); the dorsal; and the cervical (*b b*). The vertebræ in man are so constructed as to fit the spine for the erect attitude. They are arranged in the form of a pyramid, with the base below, and admit of a considerable amount of motion, but always so arranged that the centre of gravity is brought within the base. To the vertebræ the ribs (*f f*) are attached, and brought together in front by a broad bone called the sternum (*e e*). The thorax, or chest, is thus formed, and in man it differs from the monkey by being shallower and more compressed in front, and

wider from side to side: by this means the tendency of the trunk to press forwards, as it were, which is seen in the lower animals, is prevented.

We now turn to the upper extremities. They are attached by means of the blade-bone and collar-bone (*c c*) to the thorax. They differ not less in the two beings we are comparing than the lower extremities. In the orang the bones of the arm are much longer than those of the leg; in man they are of the same length. In the hand (*k k*), also, we observe great differences. The first thing that strikes us is the size of the thumb. In monkeys we have what is called an "opposable thumb"—a finger opposed to the others, by which grasping and handling are effected; but in man this thumb is capable of touching the points of all the fingers, whilst in the orang-outang the thumb is so small, and the fingers so long, that their tips can hardly be strained to meet, much less opposed to each other for use. It is the meeting of the thumb and tips of the fingers which enables man to use his hand at once with so much precision and power, that, of all organs that distinguish him, this has been pointed out as the most important. Even were the structure of the hand more elevated in apes, it would be of less use to them than it is to man; for it would only be when they were in the erect attitude that they could use it. But man's hand is always free, for his attitude is erect.

In all our reflections, however, on the superiority of the organs of man over those of the beasts of the field, we must not forget that they are directed to their great ends by the intelligence of the human race, and that without this power man would speedily sink below the level of the brute, and probably would shortly cease to exist.

CHAPTER III.

THE PHYSICAL STRUCTURE OF MAN AS COMPARED WITH THE LOWER ANIMALS.

In our last chapter we were comparing the structure of the skeleton of man with that of the highest of those creatures which most nearly approach him in habits and organization. We purposely selected the skeleton, in preference to any other system of organs, for comparison, as we find this hard framework of the higher animals assuming its peculiarities of structure in obedience to the requirements of the softer parts of the system, which it either supports or protects. In contrasting the conformation of man with the lower animals, we cannot fail to be struck with the numerous points of difference which exist between them. The differences are so great that it seems almost an improper expression to say that the orang-outang is a link between man and the quadrumana, as man has an organization much more in advance of this creature than it has above any of its own tribe. Man, in fact, is not merely the last link in the chain of the animal kingdom, but is a new creation, with a body as much more highly developed above any of the lower creatures as his mind is superior to the instinct and intelligence of animals. Yet the world has been called upon to adopt the idea that man has not been specially created and placed upon the surface of the earth, but that he is the descendant of some of the higher forms of monkeys. This theory (which the writer believes to be entirely erroneous) is called the theory of organic

development, and it supposes that the various forms of animal and vegetable life, called species, have not been created, but developed the one from the other. Thus it supposes that cells are formed under the influence of galvanism, which at last become endowed with life; that these, on the one hand, proceed to become plants, and on the other to become animals. Sea-weeds grow into lichens, lichens into mosses, mosses into ferns, and ferns into palms, oaks, and elms. The animalcules become polypes, the polypes star-fishes, and these again pass on to fishes, reptiles, birds, and mammals, till at last, by the continued process of improvement, the race of man came into existence.* Now, had we nothing but the forms of the lower animals to guide us to a rational history of creation, we might, influenced by the close resemblance in structure in many kinds of animals, come to the conclusion that it was not impossible for one to produce the other; but when we come to compare man with all other animals, we should find that he left them at so great a distance, that here, at least, our explanation would not hold. But when we examine the facts of history, and find that in all time we have no single observation to prove that a lower animal can produce a higher one, and each creature produces its own species and no other, we are driven to the conclusion that the production of every species of animal and plant, as well as man, was an especial act of creative power on the part of Deity, and that he has left no portion of his creation to the mere consequences of material laws.

Let us, however, now return to our comparison between the structure of man and the orang-outang, as we shall find that this examination will materially assist us in our subsequent inquiries with regard to the differences that exist amongst the races of men. In regarding the skeleton of the lower animals, as compared with man, nothing is more remarkable than the position of the head. In man the head is placed upon the top of the spinal column, in such a manner that its whole weight rests directly upon the erect spine. It is on this account that a small amount of muscular power is capable of giving to the human head the various movements of which it is susceptible. On examining the human body, we find a number of small muscles attached to the cervical vertebræ (Fig. 1, p. 357, *b b*), and to the base of the skull, by which the head and face are moved up and down, and from side to side, adapting it to the various positions it assumes under different mental states, and in the exercise of its functions. When we examine the lower animals, we find that the skull is placed obliquely upon the cervical vertebræ, so that with the horizontal position of the spine it gravitates toward the earth. This obliquity is less in monkeys than in the horse, ox, and elephant; and in these latter animals a powerful ligament, called by anatomists the *ligamentum nuchæ*, is extended from the base of the skull to the cervical vertebræ, for the purpose of keeping the head in its proper position in relation to the spine. In animals that are eaten this powerful ligamentous band is known as "pax-wax," or "pack-wax."

The form of the skull, and the relation of the face to the upper portion of the skull, are very different in the lower animals and man. In the former we find the upper and lower jaws projecting greatly, so as to elongate the face; whilst the skull is thrown backwards, and, as it were, behind the face. This projection of the muzzle is very characteristic of the lower animals;

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* See "Vestiges of the Natural History of Creation."

and as we pass from the less developed to those which approach man in structure, we find the jaws projecting less, and the skull brought more forward, till at last they assume a somewhat human appearance. This is the case with the monkeys, and especially the orang-outang; but the skull of this animal presents a wide contrast with that of man (Figs. 1 and 2) in these particulars. In order to appreciate the differences between the face and the skull of various animals and man, different plans have been proposed, but that of Camper is most generally followed. This consists in drawing a line from the external opening of the ear to the lower edge of the opening of the nostril. If another line be now drawn from the side of the chin, falling upon the most prominent part of the forehead, it will form an angle with the first line, more or less acute according to the greater or less prominence of the skull and projection of the jaws. If we draw these lines in the crocodile, we shall find that they correspond, and there is no appreciable angle. Cuvier gives the following as the result of the measurement of this angle in various animals:—In the Horse it is 23 deg.; Ram, 30 deg.; Dog, 35 deg.; Orang-outang, 56 deg.; European adult 85 deg.

It should, however, be remarked that these measurements differ within certain limits amongst all creatures. The difference is very considerable in the various races of men. Thus, in the Negro races (Fig. 3), we find this angle more acute than it is amongst the races who inhabit China, or the wild Indians of America; whilst in the European it is more nearly a right angle than in any other.

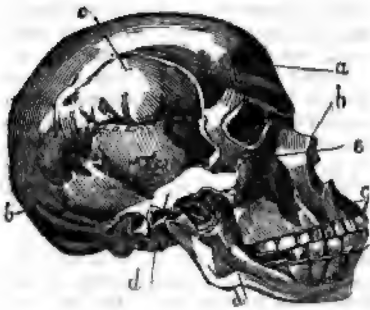

Fig. 3.—SKULL OF NEGRO.

a Frontal bone.	*e* Cheek-bone.
b Occipital bone.	*f* Lower jaw.
c Temporal bone.	*g* Upper jaw.
d Zygoma.	*h* Nasal bone.

Another remarkable feature connected with the organization of the head is the character of the teeth. Man is distinguished from all other animals in the equal length of his teeth. In all the lower animals we find the teeth overlapping each other, and thus producing an irregular line, where they are closed one over the other, and meet together. The vertical position of the teeth of man produces also the prominent chin, which is a very characteristic feature in his face. Another peculiarity in the face of man is the prominence of the bones of the nose (Fig. 3, *h*), as compared with the diminished protrusion of the upper jaw, and the projection of the forehead; so that the nose becomes an organ influencing the whole aspect of the countenance. The whole of these distinguishing characters of the skull and face of man have relation to his erect position, as we immediately recognize in the diminished length of the muzzle, the broad flat face, and expanded forehead, the structure of a creature that could not use its mouth as an organ of prehension, for the purpose of taking its food from the ground, or even for laying hold of the fruit of trees, as is the case with monkeys.

It is not, however, alone in the hard parts, or bones, that we find man differing from the rest of the animal kingdom. To each of the various bones of the skeleton in the living body there are attached muscles, which have

the power of moving the various limbs, and securing the activity of the whole frame. These muscles are adapted to the special need of the system; and although, in the power these muscles possess over the movement of the body, man may not appear to have so great advantages as many animals in running, climbing, leaping, and flying, yet in his intelligence he possesses a power of controlling these muscles: this enables him fearlessly to contend with the strongest animals, and to subdue them to his own wants and requirements. The structure and position of the heart, and the distribution of the great blood-vessels, have all reference to the erect posture in man. This is seen remarkably in the form of the blood-vessels which enter the head, and which are so constructed as to allow of a free passage of blood to the brain. It is on this account that a long-continued stooping posture is so injurious to man, and frequently ends in an attack of apoplexy, arising from the too great facility with which the blood in this position enters the head.

The great nervous mass called the brain is larger in man, in those portions devoted to the exercise of the functions of the intellect, and the convolutions are deeper and larger, than in any of the lower animals. This large brain is connected with the development of those higher mental powers, which, after all, constitute the most remarkable distinction between man and the brutes. As a power under the direct control of his intelligence, voice is one of the distinguishing characters of man. Although many animals may have the power of producing sounds through their larynx, and these may be indications to others of certain feelings, or even mental conditions, there is nothing corresponding with human *language* amongst them. At any rate, they have no power of indicating by signs these sounds, and thus of handing down from generation to generation the knowledge they have previously acquired. With this power in man we find remarkably connected his capacity for progress. He accumulates his knowledge, and each generation, as it passes away, leaves the world richer in facts, thoughts, and ideas than it found it: thus the habits of man become changed as successive generations of his race pass away. But this is not the case with any of the lower tribes of animals; they are probably the same to-day as they were when their first progenitors appeared upon the earth. The dog, the pig, the monkey, the elephant, are not conscious of a history, and we have every reason to believe that they are guided by the same instincts, and ruled by the same laws, now as they ever have been.

The slow growth of man, and the great age he attains, in comparison with his size, are both points in his economy which are remarkably characteristic of his race. He is not able to procure food for himself until he is at least more than three years old; but long after this period he requires the constant attention of his parents. This long dependence of the offspring upon the care of its parents gives rise to those social relations which last through life, and which afford so much happiness to man, but little of which exists amongst any of the brute creation. As far as can be ascertained, man lives much longer than any of the kinds of animals with which we are at present acquainted; for, although his average period of existence does not exceed between thirty and forty years, and many instances are known of animals living so long, yet there is abundant evidence to prove that man lives sometimes to the age of a hundred years, and that, were his attention more directed to the removal of the causes of death, and the

abolition of the practice of war, he might extend the average of his life to sixty or seventy years.

We shall not enter here into any detail of the contrast between the mental powers of man and the lower animals, but merely refer to man's capacity of reasoning from effect to cause, and his powers of proceeding to recognize, in all that exists around him, a great First Cause—omnipotent, omniscient, and omnipresent—whom he worships as his Creator, from whom he has proceeded, and to whom he hopes in spirit to return—for the most convincing argument of man's essential distinction from the rest of the animal kingdom, and his dignified position in the world in which he is placed.

CHAPTER IV.

ON THE SKIN, HAIR, EYES, AND BONES OF THE SKULL, AS LIABLE TO VARIETY IN THE DIFFERENT RACES OF MEN.

In the preceding chapters we have seen that however numerous may be the points of agreement between man and the lower animals, he is clearly distinguished from them by characters that are unmistakable in all circumstances in which he may be found. Yet numerous as are the features which distinguish man from the highest monkeys, at first sight they do not appear to be more decided than the differences which exist between the various races of men. How many are the characters, for instance, by which an individual of the black races of Africa is distinguished from one of the white races of Europe! The black skin, the curly hair, the retreating forehead, the projecting jaw, the whole frame of the one—how strongly it contrasts with the fair complexion, the long hair, the prominent brain, the retreating jaw of the other! Yet, when we come to examine accurately the differences between the various races of men, we shall find that every recorded dissimilarity may be comprised within limits very much narrower than any that distinguish man from the lower animals. Thus, although we find considerable variety in the form and length of the foot in man, we never find anything approaching the difference that exists between man and the orang-outang. We might thus take up every individual character of difference between man and man, and show that whatever may be its extent amongst the human races, it is much greater between man and the lower animals. There is, in fact, no one physical feature characteristic of the degradation of the lowest races of men in which man does not more closely resemble the highest specimens of his race than he does the most highly developed forms of the mammalia.

Let us, then, now proceed to examine some of these differences in the appearance and structure of man, and the agencies to which they have been ascribed as causes.

One of the most obvious, although perhaps not the most constant, differences between the races of men is the *colour of the skin*. This varies in all possible shades amongst the different varieties of mankind—from the fairest blondes of the European races to the deep ebony of those of Africa. All the observed varieties of shade appear to depend on the presence or absence of a peculiar set of cells in the skin. In order, however, that this may be un-

derstood, we must speak a little in detail of the structure of the skin. Although apparently very simple in its structure, the skin is nevertheless a very compound organ; and when we consider the important functions it performs, and its relations to the rest of the body, we shall not be surprised at this. It is not only the seat of common sensation, but, by means of the vapour it constantly emits in the form of perspiration, it becomes the great regulator of the heat of the body. For these purposes it is supplied with nerves, blood-vessels, and glands.

On examining a portion of skin from the palm of the hand or sole of the foot, from without inwards, we find that externally it presents a number of furrows, or lines, which are tolerably constant in particular parts of the body. On the elevations between these lines are seen a number of minute openings (Fig. 4, *b b*), which are the terminations of the glands (*d d d*) that yield perspiration. These furrows and pores are in the upper layer of the skin, called epidermis (*c c*), or scarf skin. This membrane is in some parts very thin, not exceeding $\frac{1}{240}$th part of an inch in thickness, whilst in others, as in the sole of the foot and the palm of the hand, it is at least $\frac{1}{12}$th of an inch thick. It is this portion of the skin which is elevated when what are called blisters are formed. When examined with the microscope, it is found to consist of minute flat cells, which have been formed below, and are gradually thrust upwards. Below this, but for the most part continuous with it, is another series of layers of cells (*c c*), and which were called, at one time, by the name *rete mucosum*, as it was supposed to be a separate membrane. The real nature of these layers of cells is, that they are all secreted on the surface of a tough fibro-vascular membrane, called the *corium*, or true skin (*h h*). The cells of the lower layer, called the *rete mucosum*, are softer and much less compressed than those which form the epidermis. It is amongst these cells that a certain set are found which are termed pigment cells. When separated they have a very distinct form, and are easily distinguished from all the other cells by their dark colour. This dark colour is dependent on the presence, in the cells, of a number of flat, rounded, or oval granules, not more than the $\frac{1}{20000}$th of an inch in diameter. Now, it is found that these cells are always present in the skin of the dark-coloured races of mankind, and also in those parts of the skin of fair races which are of a dark colour. It is, then, to the presence or absence of these cells that the skin is indebted for its white or black colour. Where they are very abundant, the skin has a black colour; and in proportion to their diminution are the various shades called red, yellow, brown, brunette, which are observed amongst the various races of mankind.

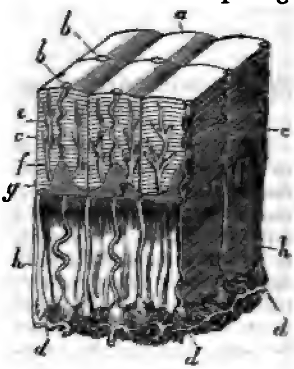

Fig. 4.*

It has always been a question of interest to the ethnologist as to whether

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* Diagram of the structure of the skin:—*a* Epidermis. *b b* Pores. *c c* Layers of epidermis and rete mucosum. *e f* Inhalant vessels. *g g* Papillæ of the skin. *h h* Corium, or true skin. *d d d* Bulbs of sudoriferous glands opening in the pores, *b b*.

the presence of these pigment cells could be traced to any external influence. As far as inquiries have extended at the present day, it appears that the tendency to form these cells is dependent in some measure on the exposure of the skin to light. As a rule, it is found that where the sun's rays are most direct—in other words, where there is the greatest amount of light—the skins of human beings exhibit the greatest tendency to develope these cells. The darkest-skinned races are inhabitants of the tropics.

This is not a mere concidence; for when the laws of light are studied, we find that its influence on organic beings is such that we are led to the conclusion that light is capable of affecting the organic constitution of bodies which are exposed to its action. In the vegetable world the most brilliant colours, the most powerful scents, and the most poisonous secretions are all produced under the agency of intense light. That exposure to light has an influence in the development of the colour of the skin is also supported by the fact that the children of all dark races are born fair, and do not become black till they have been exposed to the light of the sun.

At the same time that there exists this evidence to support generally the position that the light of the sun developes the dark colour of the skin, there are many facts to show that the growth of these cells at all is under the control of circumstances over which this external agent has no influence. Thus occasionally there are born amongst the black races individuals in whom these pigment cells are not developed, and they remain white throughout their lives. In certain parts of the body these cells are found in fair races, as in the hair and the eyes, but even amongst these races such individuals are born. They are known by the name of *Albinos*, and are remarkable for white hair, and the absence of pigment cells in the eyes, which gives the interior of these organs a red colour, from the blood-vessels reflecting the colour of the blood. This occurrence is also not unfrequent amongst domesticated animals. From these facts we must regard the dark colour of the skin as due to the constant action of light upon a system in which there is a natural tendency to develope the pigment cells.

Although colour so remarkably and evidently distinguishes human beings from one another, yet we find that throughout nature it is one of the least permanent marks of distinction between one animal and another, and even one plant and another. It will be well to bear this in mind, for when we come to speak of the great question as to whether there is more than one species of man—whether God has created two or more kinds of men, with different characters, habits, and destinies—we shall find it important to form a just estimate of the individual characters which distinguish man.

Closely connected with the colour of the skin are the appearance and colour of the hair. With the dark black skin the hair is black, crisp, and woolly; whilst with the red or yellow colour of the skin the hair is seldom woolly, or even curly, but is black, lank, and straight. On the other hand, with the fair skin the hair is never woolly, and frequently of a light colour.

The hair is an appendage of the skin, and is formed in little depressions of this organ, which are called hair follicles (Fig. 5, *a*). These follicles extend to various depths of the corium, and are always lined with cells of the same nature as those found in the epidermis. It is through the secretions of these cells that the hair (*b*) is first formed in the follicle, and then gradually thrust out from below, upwards, so that what is called the growth of the hair is secured. The hair is not a living part of the body; it has no blood-vessels or nerves, and is similar in its organic nature to the epidermis itself.

On examining a hair under the microscope, it is found to consist of three parts—first, of a coating of finely-imbricated scales, the projecting edges of which give to the hair a serrated appearance; secondly, a fibrous substance, made up of straight, rigid, longitudinal fibres, flattened and pointed at each end, and broad in the middle. These fibres are the result of the cells of which we have before spoken, formed in the interior of the follicle, and which, as they pass upward to form the shaft of the hair, are submitted to a considerable amount of compression in the upper part of the follicle. It is in these fibres of the hair that the colouring matter exists which gives the peculiar colour to the hair. This depends on the presence of the same kind of cells in the follicle which we before found giving colour to the skin. When the pigment cells are numerous in the hair follicle, the hair is black; and it is of varying shades of lightness according as these cells are absent. It is the perfect absence of these cells that gives to the hairs of the Albino and the aged their silvery white appearance. The same cause produces the colour of the hairs of the skins of various animals. The white hairs are destitute of the pigment cells, whilst in coloured hairs they are present in various proportions. In some hairs there is a third portion, called the medulla, or pith. It consists of little masses of granular particles and corpuscles, which form a dark line in the middle of the hair. It is not, however, an essential part of the hair, as it is found very frequently absent. In the skin are a number of small glands, whose function it is to secrete oily matter, which is thrown out on the surface, and in most cases it is found that these sebaceous glands open into the hair follicles (Fig. 5, *d d*). Their function is probably to facilitate the projection of the hair from its follicle, as well as to supply it with the oily matter which is necessary to its healthy condition.

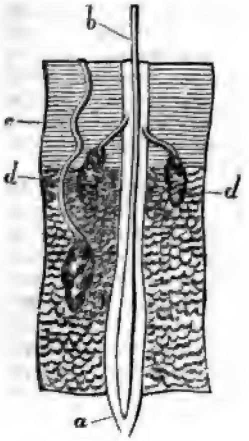

Fig. 5.*

From these facts we may arrive at the obvious conclusion that the hair is influenced by the same external agents as the skin; and we have this confirmed by the occurrence of the particular kinds and colour of hair with special conditions of the skin. At the same time we see here again that conditions of the hair come on independently of the influence of heat and light. The children of fair parents are sometimes born with black curly and almost woolly hair. In animals —for instance, the sheep—where the hair is normally white, we constantly find the occasional occurrence of a lamb that is perfectly black. Another instance of the colour of the hair being independent of climatal and hereditary tendencies is seen in


Fig. 6.†

* Diagram of a hair follicle and hair. *a* Follicle. *b* Hair. *c* Epidermis. *d d* Sebaceous glands, opening into hair follicle.
† Caucasian eye.

the suddenness with which it sometimes changes from black to grey, and which is at present quite unaccounted for.

Another of the points of difference between one of the great sections of the races of mankind and the rest is the position of the eyelids. In most of the fair races, and also of the black ones, the upper and lower eyelids will meet on a line drawn at right angles with one passing through the chin and nose, as seen in the eye at Fig. 6.

In the inner corner of such eyes, the lachrymal gland—the organ which is constantly secreting the fluid which lubricates the ball of the eye—can be seen when the eye is open.

In those races, however, which are called Mongolian, and of which we may give the Chinese and Kalmucks as examples, we find that the lids of the eye do not close upon a straight line, but that they are *oblique*, as seen in Figs. 7 and 8. The reason of this difference consists in the upper eyelid of these races being larger and more ample, so as fully to cover up the lachrymal apparatus, which is to a greater or less extent exposed in the black and white races. This gives to the eye a dull and heavy appearance, and also serves to render the eye apparently smaller. This condition of the eye has been observed in some of the lower animals, and it has been supposed to be a provision of nature for protecting the lachrymal apparatus from the effects of cold in rigorous climates.

Fig. 7.*

Another peculiarity in connection with the eye is its colour. That part of the structure of the eye which gives to it its peculiar structure is a membranous veil, called the iris, which has a power of contracting and expanding, thus affecting the size of the aperture, which we call the pupil. The cause of the colours which this membrane assumes is the same as that which produces the colour of the hair and the skin; and we find that, as a rule, where the skin is darkest there also the eyes are darkest. Pigment cells are, however, always deposited in the iris in all races, but it is only among the fair-skinned nations that we find the lighter colours of blue and grey prevailing.

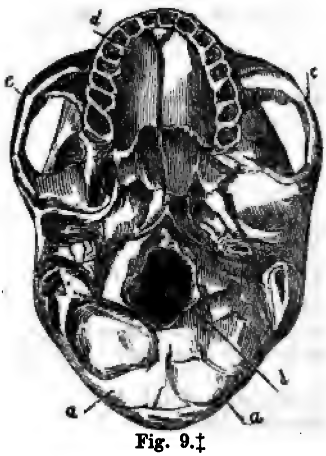

Fig. 9.‡

Fig. 8.†

* Chinese eye. † Kalmuck eye.

‡ Skull of an Esquimaux:—*a a* Occipital bone. *b* Foramen magnum. *c* Zygoma. *d* Upper jaw. *e e* Parietal bones.

Amongst the points of structure which differ in the various races of men, and produce obvious external differences, there are none more decided than those depending on the form of the bones of the skull. The differences in the general form of the skull which occur may be seen by comparing the Negro skull (Fig. 3, p. 359) with the skull of the skeleton (Fig. 1, p. 355). The parts in which the skull of the European most differs from that of the black races are those which form the upper jaw. In the black races, as in Fig. 3, the upper jaw projects, and the lower jaw is brought on a level with it, so that the mouth forms a kind of muzzle. The teeth are, in this case, oblique, and, in such case, the skull is said to be *prognathic*. When, however, the teeth are on a line with the bone of the nose, and the upper and lower jaw nearly perpendicular with the lower edge of the frontal bone, then the skull is termed *orthognathic*.

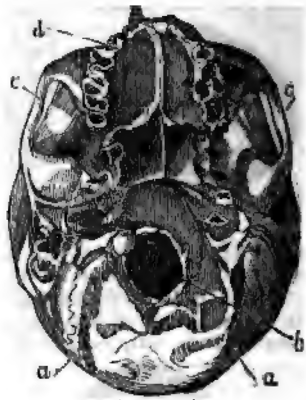

Fig. 10.*

Another point of importance is the general shape of the head, arising from the greater or less projection of the parietal bones (Figs. 8 and 9, *e e*). In the skulls of some nations, as in the Esquimaux (Fig. 9), these bones are remarkably depressed, at the same time the *zygomæ*, *c c*, are large: thus the head is narrowed, and the face made broad. Such beads are termed *dolikhokephalic*, or long-headed, whilst those in which the parietal bones project are *brakhykephalic*, or short-headed. Although such forms of the skull characterize great groups of men, yet individuals are found amongst all races in which one or other form may predominate over the prevalent one.

The other parts of the skull which are liable to differences are the bones of the nose, which are flat in some races, and prominent in others; the cheek-bones, which are either projecting or not; and the frontal bones, which are more or less advanced over the face in different races of men.

CHAPTER V.

ON THE STRUCTURAL AND OTHER PECULIARITIES IN THE RACES OF MEN

Although the colour of the skin, character of the hair, and form of the eye are amongst the most obvious differences in the races of mankind, it is not on these points that the strongest characters by which one race can be distinguished from another are founded.

In the last chapter we referred to the structure of the bones, more especially those of the head, as affording important indications of the differences between the various races of men. Accordingly, we find that Dr. Prichard has pointed out three great groups of men, which may be distinguished by the form of their head.

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* Skull of a Frenchman. Parts the same as in Fig. 9.

The first group are characterized by the *symmetrical* or *oval* form of the head. In this group the skull has projecting parietal bones, so that the head is rounder than in the others. The upper jaw-bones and the zygomatic arches (Fig. 10, *c c*) are so placed in relation to each other as to give the face an oval form. In these heads the forehead projects, and is on the same plane with the bones of the face, or, at any rate, there is no obvious projection of the lower parts of the face, the facial angle, as it is called, being greater in this group than in the others. There is no lateral or outward projection of the cheek-bones; and the teeth are so placed in the upper and lower jaws that they are almost perpendicular. It will be seen that this description will apply very well to the skull we have referred to as an example of the brakhykephalic form (Fig. 10), and which is that of a Frenchman. The people who, according to Prichard, have this form of head, are met with in countries from the Himalayan Mountains to the Indian Ocean, comprising all Hindostan, the Deccan, Persia, and Arabia. It also includes the countries of the north of Africa and the whole of Europe. The structure of the skull and bones of the face characterizing this and other groups of men communicates very marked features to the countenance. In this first group the countenance is distinguished by smoothness and regularity of features, and by an absence of prominence in any one part disproportionate to the others. The lips are small and compressed, the chin is full and prominent, and the whole face is of a regular and oval form. It is amongst Europeans that this form of skull and face is met with in its most perfect development; and the ancient Greeks, in their sculpture, have realized its most perfect forms. Such heads, however, do not exist only in sculpture, as living specimens are constantly met with equalling in their proportions those of the Greek artists; and Blumenbach has described a skull in his possession which in its structure he regarded as being as perfect as any to be found amongst Greek statues. As an example of this form of head and face, not belonging to the highest types, we may give the Abyssinian (Fig. 11).

Fig. 11.

The second form of the head is *narrow* and *elongated*. When these heads are examined, they give the impression of being compressed on each side. The zygomatic processes do not project laterally, but forwards. The cheek-bones and upper jaw project forward, not outwards; and the teeth are not vertical, having an oblique direction in the jaws. The facial angle has its lowest development in this form of the skull. This shape of head is found in the Negroes, the Alfouros, the Papuas, New Zealanders, and Australians (Fig. 12).

The countenance in these cases is the least pleasant of those of any of the

groups of which we are now speaking. The projection of the bones constituting the lower parts of the face gives to the expression an animal and somewhat ferocious character. The forehead also retires in these cases—the lips are thick and protruding—the nose is not proportionately developed, the upper part being compressed, and the nostrils wide and expanded. Such are some of the features which belong to the narrow and elongated head, and which all have agreed constitute the least beautiful form of head belonging to the human race.

Fig. 12.

The third variety of head, called the *square*, *broad-faced*, or *pyramidal*, is formed like the last, as far as the shape of the back part of the head is concerned; but it differs in the excessive outward development of the bones of the face, so that the face forms the base of a cone or pyramid. This form of the skull is represented in that of the Esquimaux (Fig. 9), which must, however, be regarded as an exaggerated type of the group.

The peculiarities of this head are caused by the projection of the zygomatic processes and cheek-bones on each side, giving great breadth to the face. The sockets of the eyes are generally large and deep in these skulls; whilst the bones of the nose, and the space between the eyebrows, are on a level with the bones of the cheek.

Fig. 13.

Of this kind of head the Mongolian (Fig. 13) may be taken as the best example. It embraces the Esquimaux, the primitive Americans, the Hottentots, the Finnish nations of Europe, the Chinese, Indo-Chinese, the Tungusians, Japanese, part of the Tartar races, and others of the northern Asiatic nations.

The countenance of these races differs from the last in projecting less, and in its much greater width from one cheek bone to another. It is in these races that the obliquity of the eye is observed, which we referred to in the last chapter. The nose is depressed—the lips are not so large as in the last class, nor so compressed as in the first—the chin is short.

Although the races of men have been thus classed together according to the form of their heads, it must not be supposed that this is one of the best ways of classifying the varieties of men. In natural history generally it is always dangerous to use a single character as a means of classifying; as the great end of all classification—the bringing together those objects which most nearly resemble each other, and the separating those which are most unlike—is often thus defeated. In speaking presently of the particular races of men, we shall see that the structure of the head is an important element of distinction to be taken into consideration; but there are other points, such as the nature of the language spoken, habits of the people, and so on, which must assist in determining the relation of one race of men to another. In fact, we have no single character that will serve for an absolute distinction between closely-allied races. We find the colour of the skin, the character of the hair, and the structural peculiarities of the head, gradually passing the one into the other, in such a way that it is only by putting all the circumstances together that any one point becomes of assistance.

Although we have not mentioned the soft parts of the body, such as the muscles which lie over the bones, as having any modifications in different races, yet it will be at once obvious that these parts must differ with the harder structure on which they rest; and it is to differences in their form that we must refer the variety of countenance which is found to accompany the particular forms of skull.

Other parts of the skeleton have been examined with great care, for the purpose of obtaining structural differences between the varieties; but none have been found so generally useful as those of the head. The bones of the pelvis (see Fig. 1, p. 355) afford considerable varieties of form, but none of these are sufficiently constant to mark the characters of races. The shapes which the pelvis assumes have been divided into four great classes—the oval, the round, the square, and the oblong. Of these the oval form is found to predominate amongst the European races—the round is most common amongst the aboriginal Americans—the square is found amongst the Mongolians, the Chinese, Turks, Malays, and others—and the oblong form in the Africans. Still, each of these forms is so common in the races in which one particular form may predominate, that they afford but slight distinguishing characters.

Amongst the black races of Africa we find indications of structural differences in other portions of the skeleton in addition to the head and pelvis. Thus the fore-arm of the Negro, in proportion to his upper arm, is longer than that of the European. The feet of these races are also often turned out, arising from the nearer approach of the knees. This is often seen amongst Europeans, and is regarded as a deformity, but is a normal condition of the structure of the black races. In addition to the turning out of the feet, they are often flat, the bone of the heel (*os calcis*) not being arched, as in the white and yellow races, but lying on a level with the other bones of the instep. The muscles of the calf of the leg are differently formed—the larger part of the great muscle, the *gastrocnemius*, being situated high up, near to the hams, at the back of the leg. These have been regarded as indications of degradation amongst the African races, and approaches towards the higher forms of the lower animals; but it will be seen that none of these points interfere with the decided differences between man and the monkey tribes to which we have before alluded.

A point of difference between individuals, and to a certain extent between races, to which attention ought to be drawn, is stature. The statements which were so frequently made in old books, of races of dwarfs and giants, seem to be disproved by the extensive researches of modern travellers. It is even questionable whether the allusion so frequently made to giants in Scripture did not refer more to the monstrous moral character of those persons than to their physical stature. Be this as it may, there is no doubt that the human frame is subject to very great varieties in size, and that from causes which are not at present well understood. It does not appear that these departures from ordinary size occur more frequently in one race than in another. Of course we are better acquainted with the most remarkable specimens of dwarfs and giants that have occurred in Europe than we are with those of other races. The most remarkable dwarf that has been known in modern times is the small American, known as General Tom Thumb. This diminutive specimen of our race is only twenty-eight inches in height. One of the tallest individuals recently known was Charles Byrne, or O'Brien, an Irishman, who measured eight feet and a quarter high, and whose skeleton is now to be seen in the museum of the Royal College of Surgeons.

There are, however, races which are distinguished from others both by the smallness and largeness of their stature. It has been the exaggerated descriptions of these people which have given rise both to the mis-statements of sober history and the fables of tradition. The height of the European races, which is about the average of that of the whole family of man, is from four feet and a half to six feet. Various circumstances, however, tend to diminish the standard of height in a nation at different times. Thus it is stated that, during the wars of Napoleon, in France the national stature of that country was reduced two inches, from the loss of life amongst the soldiers, who were the tallest men in the nation. There is, however, no reason to believe that man's height is diminishing, either in particular races or amongst the whole of mankind. This notion, which early prevailed in the history of the world, and is supported with great earnestness by the Roman historian Pliny, seems to have gained ground from the supposition that the bones of various large extinct animals were those of men. Thus we find Buffon, the French naturalist, describing bones as those of human beings, which were subsequently demonstrated by Daubenton to be those of elephants, and other gigantic animals of that tribe. So far from any degeneration in size going on in our own race, we have direct proof that such is not the case, in the fact that the iron armour which is preserved to us, and which belonged to the warriors of former times, is seldom found too large for the men of the present day; whilst the prevalence of armour too small for the great bulk of our soldiers leads to the supposition that recently the Anglo-Saxon has gained upon the stature of his ancestors.

Of races in which the stature is below the average we may instance the Hottentots, amongst whom four feet is the average height of the female, and four and a half feet that of the male. The Bushmen are of even smaller stature. But this is not a general feature of the races of Africa; for we find the Kaffirs a strong and powerful race, with an average height as great as that of the European. We observe the same differences amongst the races of America. The Peruvians in the south, and the Esquimaux in the north, are of diminutive stature; whilst the Carribbees, the Cherokees, and more

especially the Patagonians, usually attain a greater than the average height. With regard to the Patagonians, they are undoubtedly a tall race of people, but their size has been much exaggerated. Byron gives an account of one whom he judged to be seven feet in height. Bougainville says, "Among those whom we saw, not one was below five feet ten inches and a quarter, nor above six feet two inches and a half in height." It is curious that the Patagonians should be accompanied by a race—the inhabitants of Terra del Fuego—which are almost as much below the average stature as the Patagonians are above. This is, however, precisely what we see occurring in the Kaffirs and Bushmen of the south of Africa.

There can be no doubt that physical power—that is, the strength possessed by the muscles—is a great element of national peculiarity. This subject has not been much studied; but there is a popular notion that physical power diminishes with civilization; and, at any rate, it might be supposed that the largest races would be the strongest. These suppositions, however, do not appear to be correct. The only direct experiments that we are aware of are those of Peron, who performed a series of experiments with a dynamometer* on men of different nations, with the following result:—

Natives of	*Strength of the Arms.* Kilogrs.	*Strength of the Loins.* Kilogrs.
Van Diemen's Land.	50.6	
New Holland	50.8	10.2
Timor	58.7	11.6
France.	69.2	15.2
England.	71.4	16.3

There can be no doubt that the regular habits, and the constant supply of good nutritious food in civilized communities, tend greatly to maintain the strength of their inhabitants; whilst we must allow that there is an innate quality of muscle which cannot be judged by size, on which its power depends.

CHAPTER VI.

ON LANGUAGE AS A MEANS OF DISTINCTION BETWEEN THE RACES OF MANKIND.

It has only been within these last few years that the importance of employing the language spoken by man has been fully appreciated as a means of affording characters by which the classification of the races of men might be facilitated. It will be, however, speedily felt, when the nature of language is considered, that, if properly studied, it must be capable of throwing great light on the relation that exists between certain races and nations. The great cause that has retarded the application of the study of language in this direction has been the assumption of erroneous views with regard to the derivation and origin of languages. Thus, to take an example, writers

* From δυναμις, power. An instrument to measure strength.

on the English language have constantly assumed that our language has been derived from the Latin and Greek, on the one hand, and the Celtic or supposed ancient British on the other. It never occurred to the old etymologist to inquire whether Latin, Greek, Celtic, and English might not all have been derived from a common stock, which is really the case; not that we have not, and do not constantly import words from both Latin and Greek, as such words as *communicate*, *investigate*, and *condemnation*, from the former, and *geology*, *anatomy*, and *ethnology* from the latter, fully testify; but we find a vast number of words in Latin and Greek which correspond as much with words in the Sanscrit and Persian as they do with the English; and a complete investigation of the subject shows that the English, German, French, Celtic, Latin, Greek, Persian, and other languages are but branches of a common root, which has hitherto been traced to the Sanscrit.

Another obstruction to the investigation of language, and tracing its different varieties to a common stock, has been the assumption that what is recorded in the Bible of the confusion of tongues that took place at the building of Babel was the cause of all the varieties of language on the face of the earth. It will, however, be seen, by examining the tenth chapter of Genesis, that there was a great dispersion of the children of Noah before the attempt was made to build the city of Babel, and that whatever the confusion of tongues might be—and even the nature of this is doubted by theologians—it could only have been confined to that portion of the human race who were engaged in building the new city.

Although modern philologists have succeeded in tracing cognate languages to certain primitive stocks, they are not yet in a position to demonstrate that there was but one original language, or what was the probable nature of that language. We shall have subsequently to make some observations on the question, as to whether there is any evidence of more than one pair of human beings having been created. We shall then find that the demands of science, as well as all the data we possess, point to the origin of the whole human race from one pair. If this be the case, we must assume an original language, or at least such modes of expression as would originate in a common family. In the investigation of language, however, for ethnological purposes, we are not allowed to assume one language, and trace its roots through all known varieties; but we proceed from particular forms, and, comparing them with one another, ascend or pass back in time to those that were earlier, and have been parents of the first.

This process, although at first sight it might appear easy, is one that only can be pursued according to the special laws of change which it is known words in passing from one language to another have undergone. It appears that as long as a language is unwritten, it is subject to change; but these changes, although they go on more or less quickly, according to circumstances, are never sudden, violent, or arbitrary. As an instance of the kind of change that takes place, we may quote the fact that in the Teutonic languages the letter *c* of the Latin is almost invariably converted into *h*. Were it not for a knowledge of this fact, an inquirer would find it difficult to discover in the Latin word *cor* the analogue of our word *heart*; yet when we call to mind the regularity of the conversion, the little importance of the vowels in all spoken lauguages, we shall see that the *r* with its preceding letter constitutes the true root of the word. This brings us to another point in the study of words, and that is, that for the sake of denoting a relation-

ship, letters and syllables are either placed after or before certain words, called prefixes and affixes, and, in order to discover the root of these words, it is necessary to separate such additions. In such Latin nominatives as *cani-s* and *lupu-s*, and accusatives, as *cane-m* and *lupu-m*, the last letters, *s* and *m*, are no essential parts of the word, but indicate the relations of the word to which they are attached to other words in a sentence. So with such words as *am-a-bam*, *mon-e-bam*, *audi-e-bam*, the syllables *ba*, or *eba*, are the sign of the past imperfect tense, whilst the letter *m* is the sign of the person or pronoun *I*. The root of the nouns, then, in these cases, must be sought in the words *cani* and *lupu* in the nouns, and *ama*, *mon*, and *audi* amongst the verbs. As illustrations amongst the adjectives we may take such words as *gracilis*, *similis*, *docilis*, *utilis*, in which *ilis* is evidently the sign of the adjective, and the root is to be found in the words *grac-*, *sim-*, *doc-*, and *ut-*.

We must not, however, give a lecture upon language; our object is to illustrate the mode in which inquiries into language have been pursued, and have thus assisted in the grouping of the varieties of men together upon the almost infallible ground that the same race will speak the same language, and that related races will have related languages.

In the ascertaining the relation of languages to each other there are three principal methods by which the relation between the different words that compose a sentence is indicated. Of these three different methods the Chinese, the English, and the Latin and Greek may be taken as examples. In referring to the roots of words in Latin, we spoke of the prefixes and affixes which altered their form, and this mode of expressing the relation of words in a language is characteristic of the Latin and Greek languages, and is called the classical method. The words added are called *inflections*, and such languages *inflectional*. In such a proposition as *te-tig-i homin-em*, the *em* in the last word indicates the relation between the object (the man touched), and the action expressed by the verb *tetigi*, i.e., *of touching*. In the verb the *te* denotes the time, the *i* the agent.

Now, although the English language has inflections, as is seen in such words as *sister-s*, *touch-ed*, *lov-ed*, yet, as a language, it may be regarded, in contrast with the classical languages, as non-inflectional. Thus, instead of saying *tetigi*, we say, *I have touched*, and instead of *homin-i* we say, *to a man*.

The Chinese resembles the English language in this respect, that it has a separate word to express relations and objects, and is thus non-inflectional. The great difference, however, between the English and Chinese languages is this—that the English has lost inflections which it once had, whilst the Chinese has never acquired inflections. This produces a great difference between the two languages, as, in passing through the condition of an inflectional language, the English has acquired certain abstract terms which are not found in the Chinese. Thus when we should say, "I go *to* London," the Chinese would say, "I go *end* London." They have no preposition indicating direction. Instead of saying, "The sun shines *through* the air," the Chinese say, "The sun shines *passage* air," and so on.

In addition to these three kinds of language, we have another. Instead of the inflections being merely letters or syllables added to denote relationship, they are sometimes two words; so that inflection is developed as the result of juxtaposition or composition.

By these methods we can arrange all languages under the four following heads:—

1. *Aptotic* (from *a*, not, and *ptosis*, a case). Languages without inflections, and monosyllabic, as the Chinese.

2. *Agglutinate.* Languages which are inflectional, but which have become so from the juxtaposition or composition of different words.

3. *Amalgamate.* Languages with inflections, which cannot be shown to have originated in separate and independent words.

4. *Anaptotic* (from *ana*, back, and *ptosis*, a case). Languages which, like the English, once possessed inflections, but have fallen back from, or lost them.

In referring to language in our subsequent remarks, it will be of great advantage to make use of these terms as expressive of the form which any particular language assumes at the present day amongst the races of whom we have to speak.

CHAPTER VII.

ON THE UNITY OF THE HUMAN FAMILY.

Before we speak of the races or families of men as they have been described and classified by ethnologists, we must say a few words on the subject of the heading of this chapter. To use the language of an eloquent writer, "Does the Bosjesman, who lives in holes and caves, and devours ants' eggs, locusts, and snakes, belong to the same species as the men who luxuriated in the Hanging Gardens of Babylon—or walked the olive grove of Academe—or sat enthroned in the imperial homes of the Cæsars—or reposed in the marble palaces of the Adriatic—or held sumptuous festivals in the gay *salons* of Versailles? Can the grovelling Wawa, prostrate before his Fetish, claim a community of origin with those whose religious sentiments inspired them to pile the prodigious temples of Thebes and Memphis—to carve the friezes of the Parthenon—or to raise the heaven-pointed arches of Cologne? That ignorant Ibo, muttering his all but inarticulate prayer—is he of the same ultimate ancestry as those who sang deathless strains in honour of Olympian Jove, or of Pallas Athenè—or of those who, in a purer worship, are chanting their glorious hymns or solemn litanies in the churches of Christendom? That Alfouro woman, with her flattened face, transverse nostrils, thick lips, wide mouth, projecting teeth, eyes half closed by the loose swollen upper eyelids, ears circular, pendulous, and flapping, the hue of her skin of a smoky black, and (by way of ornament!) the septum of her nose pierced with a round stick, some inches long—is she of the same original parentage as those whose transcendent and perilous beauty brought unnumbered woes on the people of ancient story, convulsed kingdoms, entranced poets, and made scholars and sages forget their wisdom? Did they all spring from one common mother? Were Helen of Greece, and Cleopatra of Egypt, and Joanna of Arragon, and Rosamond of England, and Mary of Scotland, and the Eloises, and Lauras, and Ianthes—were all these, and our poor Alfouro, daughters of her who was fairer than any of them—Eve? The Quaigua, or Saboo, whose language is described as consisting of certain

snapping, hissing, grunting sounds—all more or less nasal—is he, too, of the same descent as those whose eloquent voices 'fulmined over Greece,' or shook the forum of Rome—or as that saint and father of the Church, surnamed the 'golden-mouthed'—or as those whose accents have thrilled all hearts with indignation, or melted them with pity and ruth, in the time-honoured halls of Westminster?"

Some persons very speedily, and satisfactorily to themselves, settle this question by reference to the authority of Scripture, in which they imagine we have an undoubted record of the creation of a single human pair, from whom all the race has sprung. We have already had occasion to state that the object of the Bible was evidently to reveal spiritual truths to man, and not to record scientific facts; and consequently, where the apparent interpretation of Scripture and well-observed facts are at variance, we must seek by patient inquiry to reconcile the discrepancy. By this process it will be found that sometimes our interpretation of Scripture is incorrect, and sometimes the supposed facts of science. It is certain, from all that has taken place, that no lover of the Bible need be alarmed for its authority, and that no lover of science will feel that the Bible is an obstructive of truth. In the question before us we find an illustration. We think there can be little doubt on the minds of those who read candidly the narrative of the first appearance of man on the earth in the Bible, and the subsequent connection of many of the religious doctrines of the Old and New Testament with that narrative, that the whole would leave the impression that the human family had its origin in a single pair. This inference has, however, been controverted; and we find Professor Agassiz giving the sanction of his very distinguished authority to the theory that there have been several origins or first parents of the human race; and, endeavouring to reconcile this theory with Scripture, he points to those passages in the early parts of the sacred record in which the "sons of God" are spoken of in contradistinction to "the daughters of men;" the latter being regarded as the children of races distinct from those of Adam. But the weight of criticism, entirely independent of theological views, is sufficient to demonstrate the unsoundness of the support that Professor Agassiz seeks for his theory from the Bible; and we shall find that the result of scientific inquiries on this subject, as one connected with the natural history of the human race, is in favour of man belonging to one species.

But here we must stop to inquire what is meant by the word "species;" and as it so frequently occurs in natural history, our readers may not be unwilling to enter upon the inquiry as to its import. Many are the definitions given of this word. "A species," says one writer, "is a collection of individuals which resemble one another more than they resemble anything else." Cuvier defines a species to be "the collection of all the beings descended the one from the other, or from common parents, and of those which bear as close a resemblance to these as they bear to each other." De Candolle says a species is "all those individuals which mutually bear to each other so close a resemblance as to allow of our supposing that they may have proceeded originally from a single being or a single pair." In these definitions we see that there are two leading ideas that go to make up our notion of a species. First, the *resemblance* of objects one to the other; and secondly, their *descent* from a single being or a single pair. It will, however, be very obvious, on a little reflection, that either or both of these ideas are

adopted as convenience suits, when the question of a particular plant or animal being a species or not is discussed. Thus, with regard to plants, the question of descent is seldom raised amongst botanists; and the thirty or forty thousand plants that have been described and named have been regarded only in the point of the resemblance of their characters. Resemblance alone, however, is quite insufficient to establish firmly a species, as there must always be a discussion as to the amount of resemblance, or the number of similar characters, which shall constitute a species; and thus the number of species would always vary, according to the opinions of an individual naturalist. And this has really been the case in those departments of natural history where resemblance alone has been the guide to the determination and description of species. Thus we find that those zoologists who have set aside the idea of descent have proceeded to divide into species the different forms which the domestic cat and dog assume; and in this way they might go on refining till individuals were called species, and the word would cease to be a collective one. It is in this spirit, and with this notion of a species, that many writers have examined the human family, and finding that by certain characters of resemblance they could bring together collections of individuals, they have not hesitated to call these groups species.

Such an idea of species, it must be evident, would lead to endless difficulties in science; and since, in the popular use of the word, the idea of descent from a common parent is always involved, it is necessary that this meaning be constantly attached to its employment. The objection that has been raised to this use of the word is, that the origin of a species in a single being or a single pair must be hypothetical, as no one could witness the creation of a plant or animal to describe it as a fact. It is, however, very evident, that if we abandon the theory of the transmutation of one species of animal into another, which we have previously seen to be utterly untenable, we must adopt the theory that the collections of individuals, which we call species, have originated with one being or one pair, or with many beings or many pairs. We cannot enter at length into the discussion of this question; but we may just allude to the fact, that Professor Agassiz adopts the notion that in the creation of all plants and animals, including man, several individuals or pairs, as the case may be, were created identically alike, and distributed over the surface of the earth. He thus maintains that although man has no unity of descent from common parents, he yet has a unity of nature, which is a far higher bond than any conferred by descent.

Although Professor Agassiz thus contends for the multiplicate origin of the human race, he does not maintain that man is of several species. But there are reasons which compel us to adopt the hypothesis of the origination of all species in a single being or single pair, as the only rational explanation of the phenomena of creation. If we suppose that more than one individual or pair of every plant or animal were created, we can set no limits to the time in which they were produced; and the evidence which we have of the particular ages of the strata of the earth, from the animal remains they contain, would thus entirely fall to the ground. To give an example, we may take the fossil called a *Trilobite*, which is found in the Silurian rocks of England. These rocks are known to be the oldest in the series of strata of the earth; and in reliance upon the fact that the identical

creatures which have been produced in one period of the earth's history are not reproduced in another, the geologist concludes that all rocks with trilobites, identical with those in the English beds, belong to the same period, and are of the same age. Now, the supposition that several individuals of the same form were produced at different periods of the earth's history would at once upset all these conclusions.

Nor are there any facts in the distribution of plants or animals on the surface of the earth, or in the waters of the ocean, that cannot be accounted for on the supposition that all species of plants and animals have originated with individuals or pairs, which have radiated from the spot where they were created, as from a centre, although some of them are most widely distributed over the inhabited globe. For the researches which demonstrate the possibility of the most widely distributed species of plants and animals having proceeded from a common centre, the world is deeply indebted to Professor Edward Forbes.

If, then, this hypothesis is found to be necessary to the maintenance of the first principles of some branches of science, on the one hand, and that no objection can be raised against it, as not explaining the phenomena of the distribution of plants and animals on the surface of the earth, on the other, we must admit it as an inferential fact, which may be confirmed by other observations. Whatever evidence, then, we have, either through history or tradition, of the descent of man from a single pair, affords support to the theory of the individual origin of all species.

Taking, then, the two ideas of resemblance and descent as necessary to the use of the word *species*, we shall be better able to understand and answer the question as to whether all human beings are of one species. In order to do this we must ask two other questions. The first is—Are the characters afforded by the families of mankind of such a kind as to present no obstacle to their being regarded as the offspring of common parents? And the second—What is the evidence to prove that the present families of men have been derived from a single pair? To answer these questions fully would take us over a very wide field, and we will only simply indicate here the direction which inquiry should take in order to be satisfactory.

With regard to the first question, the point that naturally suggests itself is as to whether we have, in the history of the animal kingdom, any evidence that creatures known to have been derived from common parents vary as much among themselves as the various races of men. Here we are at once met by a number of cases in point. Let us take the dog as an example. There is probably as much difference in mental character and physical appearance between the Italian greyhound and the Newfoundland dog, as between the Australian and the European; yet all the evidence, as far as it has been collected, goes to prove that all dogs have had a common origin. Whether that origin be the wolf, or a dog that was originally wild, and is now lost in its domesticated descendants, is not the question. The known changes which have been produced in the breeds of dogs in a few centuries warrant the conclusion that they are all descended from common parents. Cuvier once said that if we were to admit that the present varieties of the dog were permanent, and had different descents, you would have to admit no less than fifty species of dog.

What is true of the dog is also true of the swine. In the case of the hog

the evidence is positively even more conclusive, as amongst the farmers of this country this creature has undergone such changes through breeding as to constitute between some varieties a much greater anatomical difference than exists between the races of men. Some swine have solid hoofs, as those of Hungary and Sweden; others have five toes, each with its own hoof; and there is another race with toes half a span long. The wild hogs of America speedily acquire the characters of the wild boar in Europe; whilst their backs assume every shade of black and white, and their hair every variety, from the strong pointed bristle to a woolliness almost approaching the sheep.

The study of the varieties of the ox, the horse, the sheep, the goat, the cat, the rabbit, would afford abundant evidence that differences as great as those observed amongst the races of men actually occur amongst animals.

Another important class of facts, in determining the question we have proposed, is that which shows that certain external influences, such as heat, moisture, light, food, and habits, are capable of producing effects upon the physical condition of man which would render it probable that, in the course of centuries, the decided differences which we find now to exist might have been produced. The study of this class of facts has led to conclusions entirely favourable to a unity of species in the human race.

With regard to the answers to the second question we have propounded, we have before alluded to the evidence afforded by the account of the creation of man in the Bible. In addition to this evidence, we have the traditions which exist amongst various races of a descent of all from a single pair. Again, the evidence afforded by the study of the languages of mankind is increasingly in favour of the notion, that all languages are derived from a common stock, and every day is producing fresh evidence to this effect. How confirmatory this is of the view of the origin of the human race in a single pair we need not dwell upon here, after what we have already said.

In concluding this part of the subject we would say that we have rather aimed at assisting inquiry into it than deciding upon it. We feel, however, compelled to add, that we think the weight of evidence is in favour of the view that the human race constitutes but one species, and that God "hath made of one blood all nations of men."

CHAPTER VIII.

ON THE VARIETIES OF MEN.

In the preceding chapter reasons have been given for the belief that all the various races and nations of men constitute but one species, and that they are all derived from a common stock or pair. A question has often arisen as to which of the types or forms that man is now found to assume most nearly resembles the original stock. In other words, what are the physical

features that distinguished the first man and woman, the parents of our race? This question might appear to admit of easy solution by referring to the features which at present distinguish the races that inhabit those parts of the world in which man was first created. But could we be certain of the exact spot in which man was first placed, it would be dangerous to infer that he resembled the races of men which are now inhabiting that spot, as we have abundant evidence to show, not only that man alters in his physical character, but that races migrate from one country to another, and also have frequently supplanted each other by conquest. Neither is it by any means certain what was the exact position of the "garden of Eden," in which, in the Bible, we are told the first parents of mankind were placed. Most theologians are agreed that the country referred to was an eastern country, and that it lay east of Palestine, the place where the writer of the sacred narrative was placed. An eminent theologian* says: "The garden of Eden was probably situated on the southern slope of Armenia; for the greater part of this country, constituting an elevated table-land, with numerous ranges of higher mountains rising above it, is intersected in all directions by rapid streams; and here the Euphrates and Tigris have their rise not far from each other. But Eden itself may have embraced the fairest portion of Asia, and a part of Africa. The probability is, however, that it was limited to that portion of Asia which is bounded by the Indian Sea, the Persian Gulf, and the Arabian Desert, on the south; by the Caucasian Mountains, the Caspian Sea, and Tartary, on the north; by the chains of Taurus and Amanus on the west; and on the east by the high land which, in the steppe of the Kirghis, connects the western ridges of the Altai Mountains and the Himalaya range, about the sources of the Ganges, comprehending a tract lying between 25° and 40° north latitude, and between 30° and 80° east longitude."

Quite independently, however, of any inference from the record of the creation of man in the Bible, we have evidence of the origin of man more especially in Asia. Thus the investigation of the languages of man constantly carries us back to some common origin in Asia; and if we allow physical conformation to assist, the evidence is almost complete. Wide apart as the inhabitants of the islands of the South Seas and the American Indians may appear, it is found that they are closely connected by language; whilst from America to Asia we find a transition in the Esquimaux, who speak a language allied to that of the aborigines of America, and who have a physical conformation which allies them with the Chinese and the great mass of the Asiatic nations. The languages of the modern races in Europe are clearly traceable to one of the earlier Asiatic languages—the Sanscrit; and the term Indo-Germanic embraces those nations of Europe, as the English, French, Germans, and many others, who are evidently of Asiatic origin. The nations of Africa seemed, at one time, to form an exception to the possibility of tracing the present races of mankind to a centre in Asia; but recent researches have shown (more especially those of Dr. Latham†) that the languages of the African continent have so much in common with those spoken in Syria and Arabia, that the two have been most probably derived from a common Asiatic centre.

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* Dr. Harris's "Man Primeval." † "Varieties of Man."

What may be the precise nature of the influences which have caused so much difference to exist between the individuals of the human race we are unable to say; but instances are constantly occurring which seem to show us how possible it is that all the varieties of human beings have occurred in a common family. Even amongst the races of our own island, when exposed to circumstances which deprive them of their usual nutriment and means of developing the civilized instincts of mankind, we find that they sink in character, and become physically degraded to a level with races whose

Fig. 14.—GROUP OF AUSTRALIANS.

features, at first sight, are very far removed. We have given an illustration (Fig. 14), consisting of a group of Australians, who are receiving one of their number who has been clothed and presented with a looking-glass by the officers of the French ship *Astrolabe*. We need but to travel across the Irish Channel to see many groups of our Celtic fellow-subjects who have been reduced by famine and disease to a degraded condition closely bordering on that of these savages.

Although the colour of the skin and the character of the hair give so very decided an appearance to many of the races of man, yet there are on record a great number of cases in which individuals, with hair and skin of one colour, have given birth to children with hair and skin of another colour and character. Dr. Prichard enumerates a great number of instances of individuals with yellow hair and fair skin, amongst tribes with dark hair and skin; and in the temperate regions of Asia whole tribes, evidently descended from dark-coloured races, presented the light colour. The Jews, as we shall have occasion to see, were originally, undoubtedly, a dark-skinned and woolly-haired race; but it is well known that the Jews of Europe very frequently present the characteristics of the lightest-coloured

races. On the other hand, we have constantly individuals, born of white parents, having woolly hair, a dark skin, and other approaches to the black varieties of men. Even whole nations—as the Germans—have presented a tendency to become darker.

There is also evidence to prove that even the forms which the bones of the head assume amongst different nations are not fixed. Amongst the most highly developed races, having the most perfect forms of skull, we constantly see individuals with the projecting maxilla, which is prevalent amongst the lowest tribes; whilst, on the other hand, individuals are often seen amongst the least civilized races presenting forms of the skull approaching those of the most cultivated nations. Facts such as these are constantly accumulating, and we are bound to say that they clearly point to the derivation of the human race from one pair; and we have already seen that evidence points to Asia as the original locality of the pair.

A very natural question arises here as to whether we have any natural-history evidence as to the length of time man has existed on the surface of the earth. The ready answer to the question of the age of man's race is the authority of the Bible, or rather our interpretation of its import. In this question, as in most others, the lover of the Bible need not fear the results of scientific investigation. Recent inquiries into the history of the human race have resulted in the confirmation of the historic record contained in the sacred books of the Israelites, and have also disproved the statements of those who, relying on fabulous accounts of documents in the possession of the Chinese and Hindoos, have given to the human race an absurd antiquity. Geology reveals to us very clearly the fact, that man has not been created from the earliest period at which animal and vegetable life have appeared on the surface of the earth. Geologists can point to strata which were successively deposited at the bottoms of oceans and great rivers, and which present, for a long succession of ages, no evidence of the existence of human beings. These rocks unfold a condition of the earth's surface, by which this world was gradually prepared to receive its highest and most potent inhabitant—man. Estimates have been formed by Sir Charles Lyell and others of the periods of time required for the production of certain changes upon the earth's surface; and comparing geological changes with the evidences of the existence of man, all the principles of the science of geology support the notion that man is one of the most recently created beings upon the surface of the earth. The same evidence is also in favour of the supposition that many of the animals and plants by which man is surrounded at the present moment are contemporaneous creations with himself. What the exact date of man's creation is, science cannot answer. Dr. Latham has, however, shown that the arguments raised in favour of a much higher antiquity than is given in the books of Moses, from the civilization of the Chinese, are of no value; and he has also pointed out* that that civilization is much more modern than the Chinese believe.

Some writers, again, looking to the great length of time that it takes at present to produce any change in a language, argue from hence that in order for the present languages of the earth to have all been produced from one stock must have taken periods of time much more vast than any granted

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* "Varieties of Man."

in the Mosaic chronology. Without, however, undertaking to vindicate literally the chronology of the interpreters of the Hebrew record, we would observe that all languages would undergo much more rapid changes before writing and printing were introduced than after, and that a few centuries might have effected, in the early history of our race, changes which could now only occur in thousands of years. We shall not here, therefore, attempt to decide for or against an antiquity somewhat higher than that ordinarily assigned, but content ourselves with remarking that all the scientific evidence is opposed to an age for the human race greatly exceeding that which is ordinarily deduced from the historical records of the Bible.

We shall now proceed to speak more in detail of the various races and nations of mankind; and, in order to do this, we must adopt some system of classification. It is not, however, an easy thing to select from the various classifications that have been given by writers on the natural history of man, that which, whilst it secured the great objects of all classification—the bringing together those objects which most nearly resemble each other, and the separation of those which were most distinct—should be most readily comprehended and applied. Formerly writers on man thought it sufficient to classify his varieties—as black, red, and white—but such an arrangement is exceedingly artificial, and will not bear extensive application. The colour of the skin and hair, however, is by no means an unimportant element in the characters of any particular groups of human beings. Cuvier, the great French naturalist, in his work on the animal kingdom, refers all the varieties of men to three families—the Caucasian, or white; the Mongolian, or yellow; and the Ethiopian, or Negro.

Fig. 15.—MONGOLIAN.

The Caucasian group has been so named on account of its supposed origin in the group of mountains called Caucasus, situate between the Caspian and Black Seas, whence it has extended all around. In this group are included ourselves and the principal European families. It is characterized by the oval form of the head, and the fair complexion of the face. It includes Asiatic as well as European races.

The Mongolians are supposed to have originated in the Altai Mountains. They are distinguished by their projecting cheek-bones, flat visage, narrow and oblique eyebrows, scanty beard, and olive complexion (Fig. 15). The Chinese are regarded as typical of this race. It includes also the Japanese, the Kalmucks, the Tartars, the inhabitants of the South Sea islands, and the Americans.

The Ethiopian, or Negro race, is confined to the south of the Atlas chain of mountains in Africa. Their skin is black, their hair crisp, the skull compressed, and the nose flattened (Fig. 16). They are regarded as the lowest types of the human race; and Cuvier says that "the projecting muzzle and thick lips evidently approximate them to the apes." Those, however, who will visit the Zoological Gardens in Regent's Park at the present moment, and compare the habits and antics of the orang-outang, the highest of the ape tribe, with the lowest types of this degraded form of the human race, will see that the approximation of these men to apes is only comparative, and not real. These divisions by Cuvier have been very generally adopted; but many writers have separated the American-Indian and the Malay and Polynesian races. Thus Lawrance, in his *Lectures on Man*, includes all the native Americans under a separate class, as well as the natives of the islands of the South Seas and the Indian Archipelago. Dr. Prichard, to whose labours ethnology owes so much, recognizes seven classes, of which we need but give the names.

Fig. 16.—ETHIOPIAN RACE.

1. The *Iranians;* including the European races, and all the Caucasians of previous writers.
2. The *Turanian;* having the characters of the Mongolian variety of others.
3. The *Native Americans*, excepting the Esquimaux.
4. The *Hottentots* and *Bushmen* (Fig. 17).
5. The *Negroes.*
6. The *Papuas*, or woolly-haired nations of Polynesia.
7. The *Alfouran* and *Australian* races.

A recent writer, Dr. Pickering, who was attached to an exploring expedition made at the request of the government of the United States, has arranged his observations on the varieties of men under eleven heads. He says, "I have seen, in all, eleven races of men; and though I am hardly prepared to fix a positive limit to their number, I confess, after having visited so many different parts of the globe, that I am at a loss where to look for others."

The following is the arrangement with the definitions given by Dr. Pickering, in his work *On the Races of Men:*—

a. WHITE.

1. *Arabian.*—The nose prominent, the lips thin, the beard abundant, and the hair straight or flowing.
2. *Abyssinian.* (Fig. 11, p. 369).—The complexion hardly becoming florid, the nose prominent, and the hair crisped.

b. BROWN.

3. *Mongolian.*—Beardless, with the hair perfectly straight and very long.

4. *Hottentot.*—Negro features, and close woolly hair, and the stature diminutive (Fig. 17).

Fig. 17.—HOTTENTOT.

5. *Malay.*—Features not prominent in the profile, the complexion darker than in the preceding races, and the hair straight or flowing.

c. BLACKISH BROWN.

6. *Papuan.*—Features not prominent in profile, the beard abundant, the skin harsh to the touch, and the hair crisped or frizzled.

7. *Negrillo.*—Apparently beardless, the stature diminutive, the features approaching those of the Negro, and the hair woolly (Fig. 12, p. 370).

8. *Indian* or *Telingan.*—The features approaching those of the Arabian, and the hair, in like manner, straight or flowing.

9. *Ethiopian.*—The complexion and features intermediate between the Telingan and Negro, and the hair crisped (Fig. 16).

d. BLACK.

10. *Australian.*—Negro features, but combined with straight or flowing hair (Fig. 14).

11. *Negro.*—Close woolly hair, the nose much flattened, and the lips very thick.

In our next chapter we will give the classification of Dr. Robert G. Latham, which, as it is the most recent, and appears in one of the most able works on the subject of ethnology, we propose to follow in our remarks upon the various families of mankind.

CHAPTER IX.

ON THE RACES OF MEN.—THE PRIMARY VARIETIES OF MANKIND.

In classifying the races of men, it must be remembered that the divisions and subdivisions which are employed do not resemble those which are used in the systematic classification of plants and animals. When the whole of the species of the vegetable or the animal kingdom have to be arranged, then we divide them into various primary and subordinate groups, which are called classes, families, or orders, genera, species, and varieties. Now man himself is but a species; he belongs to a subordinate group of a large division of the animal kingdom. Zoologically considered, man is an animal

belonging to the class *Vertebrata*, the order *Mammalia*, the genus *Homo*, and species *Sapiens*. The object of our inquiry now, then, is to ascertain the observed *varieties* of the species *Homo sapiens*.

In our last chapter we glanced at the classifications of the known varieties of man adopted by different writers on the subject of ethnology. The system we shall adopt is that followed by Dr. R. G. Latham, in his work on *The Varieties of Man*. In the first place, like Cuvier and other previous writers, he adopts but three primary varieties of the human species:—

I. Mongolidæ.
II. Atlantidæ.
III. Japetidæ.

The termination in *idæ* employed here seems preferable to the use of terms such as *class*, *order*, *family*, *tribe*, or other words which have another use either in this or other departments of Natural History. It must not, however, be supposed that, by using these terms, any of the varieties of man can be traced up to a common ancestry, so that we could say, all the Mongolidæ originated with this man, or all the Atlantidæ with that man. In tracing back races we have no evidence so conclusive that any particular variety originated with a particular pair of human beings, as we have that all the families of mankind have originated in a single pair. The terms Mongolidæ, Atlantidæ, and Japetidæ are not derived from a community of meaning in the things they express. Thus the first comes from a nation, the Mongols, who occupied a portion of Eastern Asia, and were at one time the conquerors of the world, and are regarded as typical of a large portion of the human race. The Atlantidæ are entirely found in Africa; hence their name. The Japetidæ include the races of men in Europe who are traditionally descended from Japheth; hence the name selected to express them.

Fig. 18.—PAPUAN.

Before proceeding to give any account of the different nations included under these primary varieties, we will give a summary of those characters which, to a greater or less extent, separate these great divisions of mankind.

I. *The Mongolidæ.* — The people comprised under this variety have the following physical conformation. The face is broad and flat, which either arises from the great development of the zygomatic arches, or from the distance between the parietal bones on each side of the head. There is often, also, a great depression of the nasal bones, which contributes to give a flat appearance to the face. The profile of the forehead is retiring or depressed, seldom found perpendicular. The profile of the jaws is prognathic or projecting, seldom found on a level with the forehead. The eyes frequently present the peculiarity called oblique. The skin is of a mixed

character, never truly white, and very rarely of a jet black; still it often presents what would be called a black or white colour. The eyes are generally of a dark colour. The hair, as a general rule, is straight, long, and black; in some instances it is curly—rarely woolly—and more rarely still light-coloured. As examples we may quote the Indian, Fig. 13 (p. 368, and the Mongolian, Fig. 51 (p. 382), and the Papuans, Figs. 18 and 19. The two latter, however, are examples of the exceptional cases, in which this variety presents a curly, if not a woolly, rather than a long straigh hair.

The *languages* of the people belonging to this variety are either characterized by the absence of cases (aptotic), or having inflections, they can be shown to have arisen out of the union of different words (agglutinate). They are very rarely amalgamate.

Fig. 19.—PAPUAN. FEEJEE GIRL.

The distribution of this variety is very wide over the surface of the earth. It finds its greatest development on the continent of Asia, although, even there, it is found not to be entire possessor of the earth. The Persians of northern and western Persia, the Kurds, the Beluchi, the Affghans, the Tajiks of Bokhara, and the Siaposh, must all be regarded as belonging to the Japetidæ. On the other hand, although we shall find the Japetidæ the principal occupants of Europe, there seems to be little doubt that the Lapps and Finns of Scandinavia, the Magyars of Hungary, the Turks of Turkey, the Basques or Euskaldunes of Biscay and Navarre, and probably even the Albanians or mountaineers of ancient Illyria and Epirus, all belong to the Mongolidæ.

From the analogy of language, this variety is made, by Dr. Latham, to include the whole of the inhabitants of the Polynesian islands, as well as those of America. Although, at first sight, the physical differences between the Asiatic Mongolidæ and the inhabitants of the islands of the South Seas and the continent of America, might look as great as that between many of the Mongolidæ and Japetidæ, yet it has been found that even physical characters fail to afford a line of demarcation. Thus Dr. Morton of America thinks that "the squared or rounded head, the flattened and vertical occiput, the high cheek-bones, the ponderous maxillæ, the large quadrangular orbits, and the low receding forehead," are characters that would distinguish the American from all other varieties. When, however, we examine the languages of the American continent, we shall find that the Esquimaux present so strong a relation to that of the other races, that we cannot deny their affinity to the American races; and it is amongst the Esquimaux that we find a departure from the physical type of a peculiar American form, and a strong relationship with the Asiatic Mongolidæ. It is considerations such as this which have induced recent ethnologists to

regard the American Indian as a form of the variety of mankind to which the followers of Zinghis-Khan belong.

The influence of the races included under the variety of Mongolidæ must be regarded as rather material than moral. They undoubtedly form by far the larger portion of the human race, and occupy a considerable space in the history of the world. They have, by the sword, established some of the largest empires that the world has seen. China is at this moment an example. Their empires have, however, crumbled to pieces, and left no deep impression on the world. Such is not the history of the Atlantidæ and Japetidæ, the first of which includes the Jews and the Mahommedans, and the last the Greeks, Romans, and modern European races.

II. *The Atlantidæ.*—In their physical character the face is not so broad and flat as in the Mongolidæ. The jaws project, are prognathic, whilst the nose is generally flat; the forehead is retiring, the cranium dolikocephalic; that is, there is less space between the parietal bones of the skull, whilst its length remains the same, than there is in the last variety. The eyes only rarely open obliquely. The skin is mostly jet black, presenting, however, lighter shades, and very rarely approaching a pure white. The hair is crisp, woolly, very rarely straight, and still more rarely light coloured. As examples of this variety, the Abyssinian, Fig. 11 (p. 367), the Ethiopian woman, Fig. 16 (p. 383), the Hottentot, Fig. 17 (p. 384), and the Negro, Fig. 20, may be given.

Fig. 20.—NEGRO.

The languages amongst the Atlantidæ belong to the agglutinate class. They are seldom or never found with a truly amalgamate inflection.

The great district of the development of the nations which are brought together under the above definition is Africa. Perhaps there is no quarter of the globe that presents a greater diversity of inhabitants than Africa, or races of men who, at first sight, appear so evidently distinct. All previous ethnologists have placed the Hottentot, the Negro, and the Bushman in a very different position from the Assyrian, the Babylonian, the Mahommedan, and the Jew; but in Dr. Latham's classification we find these brought together under the common variety Atlantidæ. The analogy of language has led to this conclusion; and the transition from the lowest to the highest of these races is so gradual, that no investigation of their physical structure with which we are at present acquainted would be sufficient to break down the affinity discovered in their languages. No part of Africa seems to be inhabited by any races but those of the Atlantidæ. The Syro-Arabian or Semitic nations, however, which are now classed amongst the Atlantidæ, are found occupying a considerable area in the south-western part of Asia.

The people of these races are far removed from the Negro and the Hottentot, and present great symmetry of form, and considerable cerebral development.

However small may have been the influence of the lower types of this race on the world, there can be no doubt of the vast impression produced by the Semitic nations. We may pass over the early civilization indicated by the Assyrian and Babylonian empires, and fix attention on the religious history of the Jews. Here, amidst the surrounding Paganism, we find the worship of the one true God maintained by this small race amongst the Semitic nations; and through them the religion of Christ, which is destined to re-act on all the other races of mankind. It is also among these races that that compound of Judaism and Christianity, Mahommedanism, has sprung up; and however inferior it may be to the religion of Christ, there can be little doubt of the beneficial influence it has exerted on the races who have embraced it.

III. *The Japetidæ.*—This variety includes most of the nations of modern Europe. Physically they present characters superior to the two other varieties. Their face is not flat, and is moderately broad. The jaws project but little, the nose is often very prominent, and the frontal profile is not unfrequently nearly vertical. The skull is shaped generally as the last variety. The opening of the eyelids is straight, and very rarely oblique. The skin is white or brunette. The hair is never woolly, varying much in colour, frequently very light. The eyes are black, blue, or grey. We need give no example, as our own race is so good a one. The streets of London may, moreover, at all times be advantageously studied for furnishing illustrations of the great European variety of Japetidæ. Indeed, one of the interesting points of the late Great Exhibition was the facilities it has afforded, not only for the study of the industry of man, but of man himself. Nearly all the great nations of the earth have been represented there, and have afforded an opportunity for the study of their physical and mental peculiarities.

The languages of the great European races are never aptotic. They are mostly anaptotic, or having amalgamate inflections. In a few instances they are agglutinate.

Although the Japetidæ form the principal part of the nations of Europe, they do not exclusively occupy this district of the earth, nor are they confined to it. We have before mentioned the Lapps and Finns of Scandinavia, the Euskaldunes of the Basque provinces, the Magyars and Turks. It appears not to be improbable that the former were the original inhabitants of Europe, and are the remnants of a race driven away successively by the Celts and the Indo-Germanic races that now occupy this part of the world. As also we find evidence of the origin of the Japetidæ in the East, so we find traces of their existence in various parts of Asia, as in the Persians, Kurds, Beluchi, Affghans, Tajiks, and Siaposh. It is not improbable, also, that the Armenians ought to be classed with the Japetidæ.

PART V.

CELESTIAL PHENOMENA

OF THE

MONTHS.

CELESTIAL PHENOMENA OF THE MONTHS.

CHAPTER I.

JANUARY.

"Unnumbered stars ride, in their perfect beauty,
Through heaven's wide champaign."

THE clear, cold nights of winter are indescribably beautiful, when not a cloud flits across the heavens, and high winds have chased before them all murky vapours that arise from off the earth. "One starry glitter girds the glowing pole," and far and wide, from the zenith to the verge of the horizon, crowd innumerable stars of varying magnitude and lustre—some extremely brilliant, others dimly twinkling; a few verging on the horizon, but the greater number looking down, from their high stations above us, on the calm serenity of a sleeping world. "We shall have a frost," some people say; "see how bright the stars are!" and thus saying, they pass on. Others, pausing, gaze and admire the grandeur of the heavens; they desire to become acquainted with the names and relative positions of each bright star; and to such we say, "Look northwards, towards the zenith, high up in the air; there shines the Great Bear, commonly called Charles's Wain, a beacon constellation, which serves to point out the position of many others."

This constellation is readily distinguished; it forms one of the most remarkable groups in the heavens, consisting of seven prominent stars of the second magnitude, four of which are so arranged as to represent an irregular square, and the other three are prolonged into a very obtuse triangle. But in order to facilitate an accurate knowledge of such constellations as are visible during the present month, of such also as appear successively, you must provide yourself with a good celestial chart, or hemisphere, of such a size that stars of the first and second magnitude are distinctly laid down. Compare the figure of the seven stars, as exhibited in the chart, and which pertain to the Great Bear, with those in the heavens, and your eye will soon become accustomed to them. This done, examine the configuration of the neighbouring ones, which equally belong to the well-known group, and you will trace them with equal facility. We use the term "well-known," because few constellations have excited such general interest. When Milton, in poetic mood, personified Melancholy as a matron sage and holy, he thus spoke of the Great Bear:—

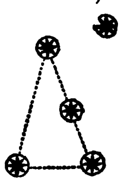
"Oh, let my lamps at midnight hour
Be seen in some high lonely tower,
Where I may oft outwatch the Bear,
With thrice great Hermes, or unsphere
The spirit of Plato!"

Our country people, who never heard of Plato, nor much concerning the shaggy occupant of Scandinavian forests, unless when exhibited as a dancer at wakes or fairs, give to the group of which we speak the appellation of Charles's Wain, or wagon; four of the stars reminding them of the four wheels of a wagon, and the three others of the horses. No other stars resemble them in their position, and by their aid many a shepherd has found his way across wild moors in winter, when snow lay deep upon the ground. Now look on the two stars which compose the hinder wheels of the wagon, and carry your eye in a straight line to a bright star above, of the second magnitude, and beaming alone in a pretty large space. This is the Pole-star; it is always stationary, and by looking full at it you may readily find the north. Although the observation is a trite one, it may not be useless to remark, that the east will be naturally on the right hand, the west on the left.

"The Pole-star hath its own deep solemn beauty,
Pre-eminent the circling stars among;
And still those stars, as if with conscious duty,
Their service render—still successive throng,
As days and years glide on; nor weary they
To tread the mighty path that circling leads,
Around that Star, to which they homage pay,
Rejoicing ever; they the Panean reeds
And dances heed not, though the glittering trains
Pass and repass o'er heaven's immortal plains."

No other constellations are associated with such pleasant remembrances as the Great and Lesser Bears. They are familiar to husbandmen; and many a wayfaring man, passing over lonely wilds, or voyager far off at sea, has been saved from inevitable destruction by observing them.

Now, if a straight line is drawn from the head of the Great Bear, crossing the meridian, and inclining a little to the north-east, it will touch the brilliant constellation of Cassiopeia, a remarkable group, containing, among lesser ones, five stars, arranged nearly as follows:—



Surely that fair lady, riding high in the air, seems as a centre of attraction to many others. Matron-like, she hath her family clustering round her, or near at hand. Methinks she might typify the virtuous woman whom King Solomon so much commends for her diligence and wisdom; whose husband trusted in her, knowing that by her skill his household would be clothed in scarlet, and himself pre-eminently attired when sitting, in the gates of his native city, among the elders of the land.

Alas for thee, "starred Ethiop's queen!" although the daughter of "bright-haired Vesta," no such meed of praise pertaineth to thy name. Thy husband and thy daughter could not "rise up and call thee blessed;" but those who look upon thee in thy nightly progress, whether above myrtle groves or over snow-clad hills, may derive from thee a lesson of eternal import.

Near Cassiopea is stationed Perseus, with Medusa's Head; Andromeda, the daughter of Cassiopea, gleams on the horizon at ten at night; Cepheus, her father, has risen considerably higher; the Swan, with a bright star in the foot of Pegasus, may be seen when the earth is free from vapours; westward appear the Pleiades, Fly and Triangle, verging on the zodiac. This glorious belt of constellations nightly reveals the signs of Pisces, Aries, Taurus, Gemini, Cancer, Leo, with the head and shoulders of Virgo.

The Lyre, Dragon, and Corona Sept are obvious in the vicinity of the Great Bear and Pole-star. Boötes, also, a northern constellation, is fully developed; and close at hand is Coma Berenices; next, and near to the meridian, Leo Minor may be dimly discerned; the Lyra appears on that line, somewhat higher up; and close to Perseus is the Cameleopard.

Beneath the zodiac, extending from west to east, the Whale, Orion, Canis Minor and Major, Monoceros, and Hydra are already stationed; southward is the ship Argo; and on the eastern horizon the Centaur has just risen.

Such is the brief mention of constellations that are now visible in the immensity of space. Concerning these, as months pass on, we purpose speaking much at large; noting, also, such celestial phenomena as pertain to this portion of our subject.

Meanwhile it is most desirable that our readers should become acquainted with historic facts connected with astronomy. Earth has her records of old time, memorial trees and ruins, which men journey far to visit, reckless of fatigue or peril; and happy is the traveller who may unearth some fragment or old coin that has lain hid for ages! The heavens, likewise, exhibit records of what has been. Those who first sought to give names to the most obvious groups inscribed upon their titles either the history of such events as they desired to perpetuate, or the names of the terrestrial objects that surrounded them, or marked successive periods for works of husbandry, or memorialized illustrious characters to whom their country had given birth.

Most authors fix the origin of astronomy either in Chaldea or in Egypt. Those regions were especially adapted for observing the movements of heavenly bodies, on account of their extended flatness, and the clearness of the atmosphere; and both equally laid claim to producing the first cultivators of this important science. The Chaldeans boasted of their temple, or tower, of Belus, from whose lofty summit they gazed upon the stars; and of Zoroaster, whom they placed before the Trojan war, and whom they extolled for his deep and acute researches into philosophy, and the study of astronomy. The Babylonians boasted in like manner concerning their colleges of priests, where the science was fully taught, and of the golden circle of Osymandyas, divided into three hundred and sixty-five parts, according to the days of the year.

The beauty and glory of the stars, designed as setters forth of blessings in store for man, and as proofs, also, of unerring wisdom, became obscured as years passed on; and when star-worship was instituted, the Chaldean and Babylonian priests, whose nightly studies gave them a minute acquaintance with the movements and classifications of the celestial lights, obtained, by this means, a great ascendency over the minds of their votaries. They could foretell precisely the moment when each star or constellation would appear on the horizon; and, calling it by some appropriate name, they professed to render it subservient to their assumed power. By these and other perversions of the knowledge which they actually possessed, they acquired an amazing political influence; and the fame of Babylon and Egypt, of their diviners and astrologers, went forth into all nations.

From Chaldea and Egypt the science of astronomy passed into Phœnicia. Her people applied the knowledge they obtained of the heavenly bodies to purposes of navigation, steering their course by the Pole-star; and becoming, in consequence, masters of the seas, they traded to regions comparatively

remote; and hence we find, in their starry archives, references to events connected with their history and commerce.

The Greeks most probably derived their astronomical science chiefly from the Egyptians and Phœnicians, in consequence of their scholars resorting to those countries in pursuit of learning. Newton conjectures that the division of the stars into constellations was made about the time of the Argonautic expedition, when, as poets tell, Jason and his fifty-four companions voyaged in the ship Argo, in order to recover a golden fleece: it is, however, more probable that such division belonged to a much earlier period, and originated before the flood. Josephus ascribes to Seth and his posterity a considerable knowledge of astronomy, and speaks of the two pillars, one of brick, the other of stone, called by his name, on which were inscribed the principles of the science. Be this as it may, it is clearly evident that the great length of antediluvian life would afford excellent opportunities for observing the luminaries of heaven, and we cannot but suppose that the science of astronomy was considerably advanced in their time.

With regard to times comparatively modern, yet previous to the expedition of Jason, several constellations are mentioned by Hesiod—that celebrated votary of the Muses, contemporary with Homer, who first wrote a poem on agriculture, and whose instructions to cultivators of the field contain reflections worthy of Socrates and Plato. Homer also refers to different groups and stars, and clothed many a thought respecting them with his wonted sublimity. In after years, Aratus, a Greek poet of Cilicia, wrote—by the desire of Antigonus Gonatus, king of Macedonia, at whose court he passed much of his life—a poem on astronomy, which, embodying the information derived from past ages with such as pertained to his own time, comprised the relative position, the rising and setting, and the number and motion of such stars as were then divided into groups. The first showed how every constellation is stationed with reference to its neighbour; what position it held as regarded the supposed construction of the sphere; and in what companionship it rose or set. This calendar of stars, though necessarily incomplete, sufficed for the use of sailors and purposes of husbandry; while the elegant and highly finished verses in which it was composed caused the poem to be translated by Cicero and Cæsar Germanicus; paraphrased by Avienus, a poet in the reign of the Roman Emperor Theodosius; and illustrated by about fifty commentators. Aratus was cited by St. Paul when, in the midst of Mar's Hill, he adverted to the superstitions of the men whom he addressed, bidding them remember that "the Deity dwelt not in temples made with hands; for in Him we live, and move, and have our being, as certain also of your own poets have said." (Acts xvii. 28.)

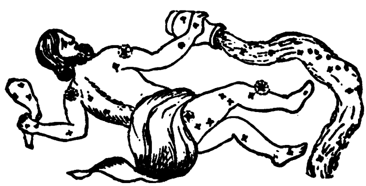
Hipparchus--himself a luminary of the first magnitude—mathematician and astronomer of Nicea, who flourished about fifty-two years after Aratus, added greatly to astronomic science. He divided the heavens into forty-nine constellations, and gave names to all the stars. He first conjectured that the interval between the vernal and autumnal equinox is one hundred and eighty-six days—seven days longer than between the autumnal and the vernal—and that it was occasioned by the eccentricity of the earth's orbit. Having also one day viewed from different situations an isolated tree growing on a wide plain, and observed the seeming change in its appearance, he was led to consider that a similar variation might be perceptible among the constellations, according to the point of view from which they were con-

templated. The same astronomer likewise determined both longitude and latitude, and fixed the first degree of the former at the Canaries.

Since then men of great abilities have arisen, and wonderful discoveries have been made with regard to astronomy in general; but to those concerning whom we speak the meed of unqualified admiration must be awarded: they led the way as pioneers along a path which few had trodden, and made discoveries worthy of all praise.

We now recur to the signs of the zodiac, which poets and star-gazers have equally admired. In past ages poets were the first to confer significant names upon those bright luminaries that nightly passed through the heavens; and it seems as if the sons of song watched also with unwearied interest these beauteous signs, that follow one the other in a circling dance; indicating, as they rise, eras of husbandry, with the coming back of punctual birds, and the opening of bright flowers.

The name of Zodiac is derived from a Greek word signifying animal; because, with the exception only of the Water-carrier and Twins, neither birds nor flowers, nor yet symbolic figures have found a place among them. To borrow the language of inspiration, "it encircles the heavens with a glorious show;" the ecliptic cuts it as it were in two, and astronomers, availing themselves of these important divisions, more readily point out the relative positions of all stars. With reference to the zodiac, the inner circle, which contains the Pole-star, exhibits by far the most brilliant and numerous constellations.



Aquarius, or the Water-carrier, belongs to the present month. No transmitted light, beaming from past ages, gives us reason to suppose that the name assigned to this constellation symbolizes any benefactor to mankind. It is rather believed to have reference to the showery character of the month, in whatever country the name was first given. Job speaks concerning water urns of the firmament, with reference to clouds, and this elegant appellation is uniformly given them throughout the East.

CHAPTER II.

FEBRUARY.

"That starr'd Ethiope queen who strove
To set her beauties' praise above
The sea-nymphs, and their powers offended."—MILTON.

MEN in all ages have regarded national calamities as the consequence of national crimes. This the Scriptures teach. When, also, the light of true religion gleamed faintly, and imaginary deities were substituted in the place of Him who is Lord of all, history speaks concerning expiatory sacrifices offered by star or idol worshippers, wherewith to propitiate whatever fancied being had become an object of divine honour.

The history of Andromeda offers a case in point. Much, too, of valuable information with regard to ancient manners may be gleaned from its various incidents, and some important lessons from considering the antagonistic

principles that bore sway in the minds of those whose names are inscribed among the stars.

First, then, is Cassiopea, wife of Cepheus, king of Ethiopia, and mother of Andromeda, first mentioned because her reckless pride gave occasion for the calamities that threatened to overwhelm her home and country. The age in which she lived pertains to remote antiquity; it forms an era in the history of mankind, on account of the Argonautic expedition, conjectured to have taken place twelve hundred and sixty-three years before the coming of our Lord, and in which King Cepheus bore a distinguished part. Those who are interested in comparing events will find that this important expedition occurred at least a century before the conquest of Egypt by the Shepherd Kings, whose great oppression rendered the name of shepherd an abomination to the natives of the country, and caused, in after years, the sons of Jacob, whose trade had been about cattle from their youth, to dwell in the land of Egypt. Saul and David had then no place in history; neither was Rome built till at least seven hundred years after; and as regards the land in which we dwell, its inhabitants were equally uncivilized and ferocious, tattooed like the dwellers in New Zealand, and mostly clothed with the skins of animals.

Authentic history can, therefore, throw but little light on the period of which we speak; but Poesy—"celestial maid!"—and her twin sister, Legend, have much to tell concerning it.

Cassiopea, say they, was a proud and capricious dame: she boasted of her beauty, and depreciated that of Juno and the Nereides—sea-nymphs who dwelt chiefly in the Ægean Sea, and often danced in choruses around their father, Nereus.

> "Is not my beauty greater far than those"—
> Thus spake the queen—"Nereides though they be,
> Pale nymphs that haunt where'er the streamlet flows,
> Or ride in sea-shells o'er the briny sea?"

The Nereides heard, and they prepared for vengeance.

Morning rose in beauty; the sun came forth from his glorious canopy of clouds; and the rippling waves of the ancient sea broke in gentle murmurs on the shore. Damsels went forth to their pleasant labours by fountain side, or to gather the golden-tinged oranges and citrons that hung in clusters beside the fields of pulse. The king was in his hall of state, the queen presiding with her ladies at their looms; there was peace within the city, and gladness in the country, when suddenly the sky was overcast, and a loud, bustling, unusual kind of wind drove the dust in clouds.

"I cannot see to go on with my embroidery," said the chief lady, whose office it was to superintend her younger companions; "we must all wait till the sky is clear again." And thus saying, she folded her hands together, and looked towards the heavens.

The firmament, however, darkened more and more; and presently a messenger came in haste to say that the river had broken its bound. Onward came the waters, rolling over their ancient limits; fields were inundated, and cottages swept away; while the terrified inhabitants rushed tumultuously into the city, which stood on rising ground; but presently the streets were overflown, and the whole population fled with one accord to a considerable eminence, which the torrent had not yet gained.

That eminence was crowned with a temple of exceeding beauty, and shaded by an olive grove. Jupiter Ammon, under the name of Osiris, was worshipped

there, symbolic of the sun, and representing the principle of light and heat; his altars were not, like those of other pagan deities, stained with the blood of human victims; his sacrificial offerings were goats, sheep, and white bulls. Even in this early period men had turned from the adoration of the true God, and substituted symbolic worship; and their high places retained a strong hold on the affections of the people, who ascended them at the dawn of day to hail the first appearance of the luminary whom they ignorantly worshipped.

The unwonted clouding of that luminary was, therefore, regarded as a proof of his displeasure. "Haste ye, priests," said the king; "consult the oracle, according to your wont; even now the frantic billows, urged by fierce winds, have reached the base of the eminence; they prepare to scale the sides." The priests made all haste; there was no lack of beasts for sacrifice, for the herdsmen had driven their choicest herds and flocks for safety to the mount; and many a terrified animal, after struggling through the current, had rushed among the crowd. Two white calves were quickly sacrificed; and priests, attired in sacerdotal vestments, and bearing in their hands branches of oak covered with acorns, entered a solemn wood, which clothed the hill eastward, within the precincts of which, and beside a rushing stream, dwelt the priestess, whom they invoked with loud cries, for already the usurping waters might be seen gleaming among the trees far down, yet reaching above the giant roofs of such as skirted the margin of the wood.

Slowly came forth the response. "Your queen," said the oracle, "has drawn upon herself the vengeance of Neptune; she has boasted of her beauty, and derided those who dwell amid rushing waters. One only offering can save her husband's realm from ruin. Let Andromeda be that sacrifice—

'A votive offering to the raging main.'

Bind her with strong cords to some sea rock, and dare not to interfere, whatever fate may threaten."

Who can describe the anguish of the parents when listening to those words of augury? They still sought to save their child, and hurried, together with their people, to the highest summit of the hill; but the waters followed hard after them, and as far as the eye could reach appeared one vast sea-like lake, covered with raging billows, each of which seemed as if urged onward by remorseless genii; high towers and domes came crashing, thundering down; tall cocoa-trees were submerged to their branches, and yet the flood increased.

"Oh, my parents!" said Andromeda, "resist no longer, I beseech you. We must all perish. See you not that the waters have gained the first grove of olives? Quick, quick! let the consecrated boats be lowered: the priests will row me speedily to the nearest rock."

And the boat was lowered: it bore a sacrifice that day such as Ethiopia had never before witnessed. The priests rowed hard, and wept in bitterness of heart; for Andromeda, the beloved of her father's house, had grown up among them. The billows helped on the boat—they seemed to run down the sides of the mount—they rushed across the plains—they went sounding towards the sea, bearing with them a freight of boats, for "She shall not die alone!" had been heard as one wild cry from the trembling multitude.

Prayers such as never had ascended from the land of Ethiopia were heard that day. They invoked neither Jupiter nor yet Neptune, nor any of those imaginary beings who were fabled to preside over the destinies of men. The terrible land-flood and the prospect of certain death had dissipated, as in a

moment, the illusions of past ages; the oneness and mighty power of some all-presiding Deity seemed to fill their minds, and to Him alone they prayed, as having the power to save.

Andromeda was firmly bound; and around her the raging billows tossed on high their crests of foam. Her eyes were closed, her hands folded on her breast: she looked like one whose thoughts were not of earth—who meekly submitted to lay down her innocent life for the saving of her father's land. Suddenly, and with a terrible rush, came up a monster from the deep—half fish and half serpent—and made towards the damsel; and as suddenly sprang forth the strong men from their boats, heedless of oracle or Neptune; but, alas! they were unarmed, and their deafening shouts were unavailing to intimidate the monster. The parents in their agony had fallen to the ground; but the hideous reptile having struggled over a sunken rock, and being in the act of sliding down the side nearest his victim, was suddenly arrested by a flashing sword—that of a stranger youth, who boldly advanced to the rescue. The conflict that ensued was terrible to witness. The reptile sought to enwrap his opponent in his flapping fins, while he lashed the billows into foam; but the stranger, eluding his attack, gave him a dire thrust, and escaped behind a jutting rock. The reptile followed him with open mouth, and would have seized upon his enemy, had not the rock proved a barrier to his further progress. One moment more, and while the hideous eyes of the creature glared furiously within reach, a rapid stroke from the good sword of the young prince deprived him of sight. Oh the terror and the gladness of that moment!

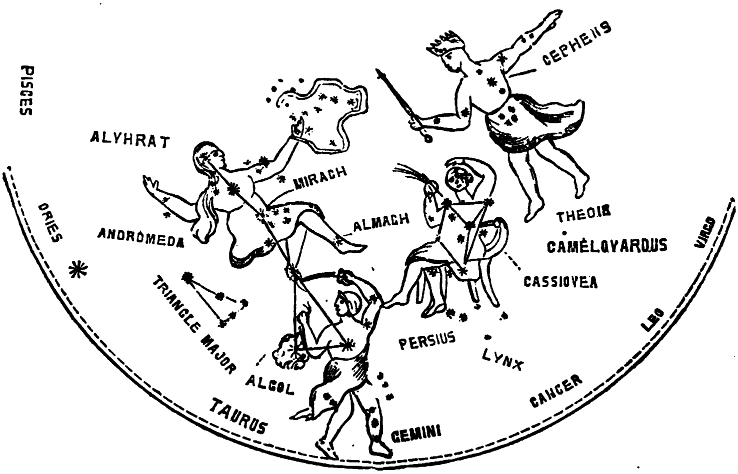
The furious serpent raged round and round; the waters smoked beneath the lashing of his tail, and his yells were horrible to hear. Happily the first thrust had entered a vital part, and his strength quickly failed. A few more efforts—a few more openings of his wide jaws, as if eager to devour his prey—and he lay dead upon the waves.

"Let us drag him out, and hang up his skin in the temple on the mount," said a troop of young men, who came running from the Libyan side. "No," said Perseus—for such was the stranger's name—"let us rather return thanks to the Ruler of heaven and earth, who alone checked the land-flood, and strengthened my arm to overcome the terrible sea-monster, who would otherwise have devoured me."

"Andromeda, thy gentle name is blended
With that bright star which near to Perseus waits,
Rising with him and waning, thou, descended
From a long line of kings, and chief estates!
Now moving through the calm and silent night,
All sorrow past, all mortal care gone by;
The stars that bear your names, with purest light,
Beam on each lone grave where your ashes lie.
And calmly seated in her starry chair,
The chasten'd mother beams effulgent there."

The courage and devotedness of Andromeda are so inexpressibly touching, that wherever her constellation becomes visible with that of Cassiopea, some affecting incidents are connected with them. The Italian peasant sings concerning the wayward queen, and her meek and devoted child, beneath the shade of olive groves. The Savoyard hails the rising of his favourite stars over rocks and waterfalls, and strikes up the merriest tune to their honour. Even the Swedish peasant, who has heard their tale in songs which have been

handed down from father to son since the days of Linnæus, associates with them that small purple flower which grows in swamps and peat bogs, amid the wildest solitudes. "This plant," said the Swedish naturalist who first discovered it in the marshy parts of Lapland, "shall be named Andromeda." The Ethiopian princess was chained to a sea-rock; the billows reached her feet, as fresh water the roots of this beauteous evergreen. A fierce dragon infested the ocean beside which her doom was fixed, as toads and other reptiles infest the abode of her vegetable prototype. Andromeda cast down her blushing head from excessive affliction, and the rosy-coloured flower hangs its petals, which grow paler and paler, till she dies away. Perseus bravely came to the rescue of the maiden; and summer—which he may be thought to symbolize—dries up the surrounding waters, destroying by his beams such monsters as lurk therein, and restoring the plant to liberty, who then carries her head, the capsule, erect.



- Star of the first magnitude.
- Star of the second magnitude.
- Star of the third magnitude.
- Star of the fourth magnitude.
- Star of the fifth magnitude.
- Nebula.

Thus closes the history of Andromeda and its associations; of Cassiopea also. He who wishes to become acquainted with the form and place of such constellations as bear their names may readily discover them by comparing the heavens with his chart; keeping steadily in view that they describe a circle round the Pole-star, and form a family group, including Cepheus and Perseus—the father and husband of Andromeda—and near them are the Dragon and Great Bear. The Pole-star, therefore, is the termination of an axis round which myriads of stars revolve; and the reason why a considerable

number seem to rise and set, whilst others are always visible, is simply that such as are further removed from the Pole-star form larger circles than those which are nearer—a fact which may be readily understood by observing the motion of a wheel: the axle never changes, but any particular point on the outer edge of the wheel describes a larger circle than such parts as are midway between the centre and the circumference.

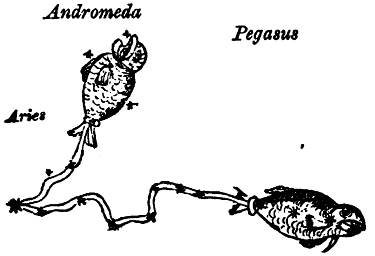
Our readers must, however, bear in mind that stars actually neither rise nor set; that this beautiful effect is caused by the daily motion of the earth on its axis, to which we owe the grateful vicissitudes of day and night. And in order to assist them in discovering that beacon star which is all-important in finding the position of many others, we shall briefly again repeat, that if we suppose the distance from the northern point of our horizon—where the mighty dome of heaven seems to rise from off the earth to the zenith, which is immediately above our heads—to be divided into five equal parts, then at nearly the height of three of those divisions gleams the Pole-star. This star is about 1° 10″ from the pole; and excepting the small circle which it therefore necessarily describes, it is always in the same position, whether by day or night, summer or winter. The southern axis, on the contrary, is not distinguished by any analogous star, or clusters, resembling the Great and Lesser Bears. Astronomers relate that none of the stars in that quarter form circles, for that all appear to rise or set. Still, however, the semicircles or portions of semicircles—usually called arcs—which they describe, seem to have a common centre at some distance below the horizon; and this may be considered as the southern end of that great axis, which is so gloriously studded at its northern point.

Circumpolar is a term usually applied to all such stars as revolve around the poles. Those which never rise nor set to an inhabitant of London, and which are uniformly visible unless obscured by clouds, or disappearing in the blaze of day, are called stars of perpetual apparition, being constantly above the horizon. This term pertains to all such as belong to the constellations of which we have just now been speaking.

Persons who watch from night to night the rising of those stars that gem the heavens will find it important to remember, that while the glittering hosts seem to move round the earth from east to west, in consequence of its daily rotation, they become visible about 3′ 56″ earlier every evening, and thus may be thought to gain nearly one whole revolution more than the sun during the year. This is occasioned by that luminary appearing to progress among the constellations of the zodiac from west to east, in consequence of the earth's annual rotation. And in order to the better understanding of this portion of our subject, it is needful to observe, that the term *sidereal* day, which often occurs, signifies the revolution of the earth on its axis in 23h. 56m.; being the time which elapses from the appearing of a star upon the meridian till its coming there again. If the earth was stationary, this period would comprise our day; but such is not the case: and the rolling ball, on which we live and move, advances nearly one degree in its daily orbit.

When, at this season of the year, the nights are frosty and the heavens cloudless, most glorious stars are revealed in all directions; we shall, therefore, defer speaking at large concerning the fixed stars till the year is more advanced, and constellations are scarcely visible in the light nights of summer.

Pisces is the twelfth and last sign of the zodiac, and although the least attractive, is one of the largest constellations pertaining to the northern hemisphere. Unlike many others, it does not consist of an isolated figure, but is composed of three parts, viz., of two fishes, at a little distance from each other, connected by a line or cord. The fishes are not large, but the line is widely extended, and lies between them in a very undulated position. No probable conjecture can be formed as regards the species, nor has any distinctive name been assigned them; they are merely represented as thick and short, with large heads, wide mouths, and forked tails, and having a kind of ring affixed to each tail, from which the cord depends. This cord, in order to comprise the greatest possible number of stars, appears flat, and somewhat broad, extending not in a straight line from one fish to another, but circuitous, and ornamented towards the middle with a kind of knot.



Astronomers have not assigned any star of the first brilliancy to this constellation; such as compose it are mostly of the second or third magnitude, and yet they are disposed so equally and regularly that the entire sign may be readily discerned.

The neighbouring constellations are those of Aries, Andromeda, Pegasus, Aquarius, and the Whale. The upper fish lies in a position perpendicular to the ecliptic, while the lower is nearly horizontal; the former verges on Andromeda and the Ram, the latter on the pitcher belonging to Aquarius, and the back and wing of Pegasus.

Among the eight-and-forty constellations which Greek astronomers derived from their Egyptian brethren, and which have been transmitted to the present day, the Fishes have retained their form and station unaltered. True it is that whereas Hipparchus and Ptolemy assigned only thirty-eight stars to this sign, Flamstead enumerates one hundred and thirteen, but no attempt has been ever made to improve its ungainly appearance. The Greeks, that imaginative race, who peopled their groves and streams with ideal beings, referred the origin of their favourite constellations to some historic event or poetic legend. It was otherwise with the Egyptians; they adopted such figures as characterize the twelve signs of the zodiac, with reference to the changes of the seasons or country occupations: the constellation Pisces therefore denotes the approach of spring, and the season for fishing.

CHAPTER III.

MARCH.

"Ye stars, that are the poesy of heaven."

None, perhaps, among the constellations are more pleasing and conspicuous, none undoubtedly more suggestive of poetic thoughts and kindly feelings, than the Pleiades, or Vergiliæ.

Daughters were they of Atlas and Pleione, or Æthra, one of the Oceanides. Their father, King of Mauritania, was equally renowned for his wisdom and great wealth; he was the master of a thousand flocks, and his gardens were everywhere celebrated for the variety of their fruits and flowers. These gardens, intrusted to a careful warder, amply repaid his care, and so widely spread their fame, that when Perseus, the deliverer of Andromeda, chanced to pass that way, he requested permission to gather some of the ripe fruit. His request was, however, decidedly refused: Atlas knew his origin, and having lent an anxious ear to the oracle of Themis, which, darkly uttered from amidst groves of laurel beside a rushing stream, foretold that the King of Mauritania should fall before a stranger youth, driven by fierce winds, and stranded with his mother Danaë on the coast of Seriphos, one of the Cyclades. This prediction, as poets tell, incited Atlas not only to refuse the rites of hospitality, but to offer violence to the stranger, who, on his part, being unequal in strength, and but slightly armed, drew from beneath his vest the terrible head of Medusa, bristling with snakes—that Medusa, one of the sister Gorgons, whom he had subdued in the deserts of Asiatic Scythia. So terrible was her aspect, men said in those far-off days, that none could look upon her without being changed into stone. Perseus therefore, who found the sisters asleep, looked not on them, but on his burnished shield, which reflected every object as clearly as a looking-glass; and, strengthened by Minerva, the goddess of Wisdom, cut off the head of Medusa with a single blow: this head he fixed on his shield, and went forth in quest of adventures. Presenting, therefore, before the sight of Atlas, that tremendous spectacle which none might look upon unharmed, the monarch was instantly changed—yet not into an isolated rock, but rather into a range of mountains, as became his kingly dignity, which mountains ran across the deserts of Africa, east and west, and bore his name, lifting their conic summits to the clouds, and often concealed by them. Hence the ancients fable that they upheld the magnificent dome of heaven, and that Atlas supported the world on his shoulders—a fable which originated, without doubt, in the well-known fondness of the Mauritanian monarch for astronomy, and from his frequenting elevated places and high mountains to watch the motions of the stars. Therefore it was that when his seven daughters were carried away by Busiris, King of Egypt, but redeemed by Hercules, conqueror of the Nemæan lion, and to whom the white poplar is especially dedicated, the father rewarded his services by instructions in astronomy, and the present of a celestial globe. This knowledge Hercules communicated to the Greeks, and from this, also, originated the fable, that Hercules eased for some time the heavy burden borne by Atlas, taking on his own shoulders the crushing weight of the universe.

Amidst the dim obscurity of this wild history, facts are yet discoverable that bear on the origin of science. They go far to show that gardening and astronomy occupied the attention of one of the greatest men belonging to a period antecedent to the historic era, but whose name, inscribed among the stars, and written, as it were, on that vast range of mountains from which the Atlantic Ocean takes its name, has been renowned throughout all ages. The existence of a celestial globe, with the giving of instruction as a reward for valour, and the passing also of astronomic science from Mauritania into Greece, are equally authenticated facts. We learn, moreover, that strangers demanded as their due the exercise of hospitality in those early ages; also the

baneful influence of obscure oracular predictions on the most enlightened minds.

Poets have sung concerning the seven daughters of Atlas and Pleione—a nymph of ocean birth; and doubtless poets in all ages, though an imaginative race, drinking of the waters of Helicon, and loving to range through a world of their own creating, preserved facts that must otherwise have been lost in the obscurity of time. We owe much to them, and in preserving a brief memorial of those seven sisters, they offer to mankind beautiful and impressive examples of filial love and sisterly affection.

The name Pleiades is derived from a Greek word, signifying *to sail*, because their rising was hailed by navigators as a favourable time for venturing to sea; Vergilia, from *ver*, the *spring*, when the Ornithian winds blew softly, and the swallow returned to her nest; when also the kite and nightingale appeared in Greece, and trees, according to an ancient Calendar of Flora made by Theophrastus, began to put forth their leaves.

Each sister, as legends tell, married an immortal being, with the exception of Merope, who allied herself to Sisyphus, King of Corinth; and her star, in consequence, became somewhat dim. It is said concerning them, that while living with their parents, they were also called Hesperides, from the garden of their father—that celebrated garden which abounded with the choicest fruits, and where grew those golden-tinted apples which Hercules longed to possess. Often in a summer evening did Atlas, laying aside the cares of state, go forth with his seven daughters amid his fruits and flowers, telling them concerning their names and natures; how the opening of one flower preceded the expanding of another, and the return of punctual birds from other climes; how, also, he guarded with jealous care those richly-loaded trees, which appeared as if covered with golden fruit, because throughout the vast extent of Africa no other monarch was believed to possess them.

Often, too, when Silence and her sister Twilight came forth with the "folding star" of the latter, shedding refreshing dews, and drawing a gradual dusky veil over those bright gardens and ample fields, where herds and flocks lay down to rest, might the gay train of nymphs be seen accompanying their sire to the summit of some near hill. "Look, my daughters," he would say to them, "on the myriads of stars that seem to stud the heavens. How beautiful, and yet how varied in their forms and brightness! Some are dimly seen, others sparkle gloriously above our heads. Yonder are Orion and Mazzaroth, and a cluster of stars towards the north. Look carefully upon them, and you will readily discern that though, like the sands upon the sea-shore, they are innumerable, and seem inseparably intermingled, they yet form groups which mostly rise and set as seasons come and go, which invariably indicate the leafing of trees, and the opening of wild flowers, and point out to the husbandman and sailor when each should plant his field or adventure on the sea."

Thus instructed, and attentive to their sire, went forth the daughters of Atlas into other realms. Alcyone, whose name is borne by sea-birds, espoused Ceryx, King of Trachima. Merope, as already noticed, dwelt in Corinth, which her husband founded. The mists of ages obscure the homes of Maia, Electra, Celeno, and Targete. Sterope married Ænomaces, King of Pisçea, a powerful and flourishing city of Etruria, and who is conjectured to have greatly assisted her husband in its internal regulations. Judging

also from the faint light that history has cast on events connected with the seven sisters, on achievements likewise assigned to their sons, and on improvements in their adopted countries, we may conjecture that each sister shed a blessing on her home, and carried to other lands the knowledge which she had derived from her sire.

Astronomers in all ages have loved to describe the Pleiades: beautiful they are, and readily distinguished among their brethren: many have admired the group of stars that bears their name, who yet are little conversant with their history. Henceforth we trust that those who seek for them in clear evenings, from the end of August till the middle of April, will remember the filial love and sisterly affection of those who are thus immortalized—their love of stars and flowers, and the hallowed influence of their domestic virtues.

Seven stars were originally assigned to this group, each of which may be distinctly seen in clear frosty nights, although of different lustre. Modern discoveries, however, have shown that although the unassisted eye can see only this restricted number, the telescope reveals a much larger assemblage. Dr. Hook, formerly professor of geometry in Gresham College, informs us that by the aid of his twelve-feet telescope, which magnified about seventy times, he discovered seventy-eight stars in this interesting group.

"Canst thou bind the sweet influence of the Pleiades, or loose the bands of Orion? Canst thou bring forth Mazzaroth in his season? or canst thou guide Arcturus with his sons? Knowest thou the ordinances of heaven? Canst thou set the dominion thereof in the earth?" Thus spoke a voice from out the whirlwind, bidding the patriarch Job consider the wonders and the glories of creation, and confess his utter inability to comprehend the ways of the Most High.

The aspect of the heavens is extremely beautiful during the present month, and, perhaps, as some of our readers may find it convenient to examine the different constellations rather at nine than ten, we shall present them with their general appearance on the 1st of March, at that hour.

Pegasus and Pisces, with several lesser constellations pertaining to the commencement of January, have disappeared; others which are still visible appear less elevated; and some have risen to a considerable height above the horizon. Orion, pre-eminent in beauty, is now in the south-west quarter of the heavens; the Pleiades, instead of being on the meridian, are due west, at an elevation of 34° above the western point of the horizon; Sirius shines west of the meridian in a direction SS.W.; Procyon and Canis Minor occupy nearly the same position; and Castor and Pollux, directly north of Procyon, have likewise passed the meridian. Thirty degrees to the westward of the zenith, Capella looks down from his starry dwelling. Men-

tor, in the head of the Whale, beams within a few degrees of the western horizon; as also Aries; while Cassiopeia occupies a north-westerly direction, though somewhat lower than in January. Deneb, in the Swan, verges on the horizon, a little westward of the north point; Vega, conspicuous in the Lyre, gleams at a short distance eastward. About 18° above the horizon the head of Draco may be discovered in a N.N.E. direction; the Great Bear has attained a higher elevation, and the Pointers are in a direction N.N.E. Cor Caroli recalls to mind the eventful era to which it owes its name, and appears in a direction east by north, about midway between the zenith and horizon.

Other constellations also deserve brief notice, as conspicuous in the present month. Hydra, of which the largest star is Alphard, or Cor Hydræ, may be discerned about 28° above the horizon, in a S.S.E. direction, beaming in its own calm beauty, and nearly alone. S.S.W. is Regulus, one of the largest stars in the constellation Leo, and within half a degree of the ecliptic. This splendid star may be readily distinguished, from being the largest and the lowest among a group of five or six stars that form a curve or figure somewhat resembling a sickle. Eastward of Regulus is the Lion's tail; and eastward, also, is the constellation Virgo, although many of its stars are still beneath the horizon: such as have risen are midway between Coma Berenices on the north, and Corvus on the south: the former consists of a cluster of small stars, lying nearly due east, and about midway between the zenith and horizon. Arcturus, the chief star in Boötes, may be discerned east by north of Coma Berenices, though at a low elevation. Farther to the north, and even nearer to the horizon, is Corona Borealis, or the northern crown: the principal star is called Alphacca—it is of the third magnitude, and 11° east by north of Boötes. This elegant constellation is easily distinguished by its six principal stars, which somewhat resemble a wreath or crown.

The sun enters the first point of Aries on the 21st of March, at which period commences the vernal equinox, although the sun is actually in the constellation Pisces; it follows, therefore, that the sign Aries does not correspond with the constellation that bears its name, and in solving this problem, which is necessary to be understood, we cannot do better than avail ourselves of the explanation given by the Rev. Lewis Tomlinson, M.A.:—

"When the sun, for instance, is said to be in Aries, it simply means that he is situated between the earth and that zodiacal constellation; and when, in olden times, he was about coming between the earth and Aries, that position was called the first point of Aries. But, in order to obtain a greater precision in naming the position of the source of light at any other period, Chaldean observers of the stars divided the circle described by him into twelve equal parts, without any very strict regard to coincidence between those parts and the clusters of stars from which they were named. Each portion was further divided into thirty equal parts, called degrees, by which arrangement the position of the sun could be determined with great accuracy. This apparent motion of the sun is from west to east, or from the sign of Aries to Pisces, and results from the progress of the earth in the same direction."

Ages passed on; and men observant of the stars discovered that the sun did not occupy the same position in the constellation Aries on the 21st of March as ancient astronomers had noted: they discovered, also, that the

difference was occasioned, not by a motion of the stars, but by a change in the point of the earth's orbit, at which the two hemispheres are equally exposed to the sun, and which is generally described as that where the plane of the equator cuts the plane of the ecliptic. This point is called the *equinox*, because day and night are everywhere equal when the sun is at the point of intersection. The *precession of the equinoxes* is a term that frequently occurs; it signifies this motion of the equinox, but ought rather to be termed the *recession*, because they appear to travel *backward*, while the signs go *forward*, and is caused by the attraction of the sun and moon for the mass of terrestrial matter at the equator. The precession is, however, so exceedingly slow, that two thousand years have been occupied in the receding of the equinoctial points through one sign, or thirty degrees, from the point where it was fixed by Hipparchus, the father of astronomy.

If, therefore, the reader should chance to meet, in astronomical works or almanacs, with such expressions as, "the Moon is in Aries," or "a conjunction will take place in Libra," he must look for this event in the cluster of stars forming those constellations, although assured that the sun, or moon, or planets, are much nearer to him than the constellations that form a kind of background, and to which they apparently belong.

Astronomers of the olden times, who determined the twelve divisions of the heavens, and marked the clusters of stars peculiar to each, gave to the three constellations, through which the sun passes during the spring, names of such animals as they most especially valued. The first was called Aries, or the Ram; the second, Taurus, or the Bull; the third, Gemini, or the Twin Goats, which were afterwards changed by the Greeks into Castor and Pollux.

These names, originally applied as they stood connected with events relating to pastoral life, gradually acquired a sacred character. Shepherds were, undoubtedly, the first astronomers; they often guided their course at night over the vast plains of Egypt and Chaldea by the stars; they observed the connection which subsisted between the passage of the sun through different portions of the heavens, and named the stars within his range after the objects most familiar to their sight. Hence their zodiac displayed the beautiful constellations above mentioned, associated with the animals by which they were surrounded, and simply recalling images of rural occupation.

It was otherwise in after years; their descendants distinguished each by characteristic attributes, and learned to regard them as objects of superstitious and idolatrous veneration.

Pan, therefore, in the earliest mythologies, is portrayed with the insignia of the goat, and Libyan Jupiter with the horns of the ram; Osiris, or the sun, assumed the same character during the vernal equinox; and both Jupiter and Minerva, whom men in after ages idolatrously worshipped, claimed alike the ægis, or goat-skin, for a breastplate.

Much of history and tradition is associated with the mention of this constellation, or rather, perhaps, of the animal from which it derives a name. The Macedonians were denominated Ægeadeæ, or the goats' people, at least

ro hundred years before the era of the prophet Daniel; and such is the igin of so strange an appellation. Those who departed from the worship the true God seem to have been given up to the wildest imaginings: they onsulted oracles, and followed whatever vague or ambiguous directions ere suggested by craft or policy. Hence it was that Coranus, the first ing of Greece, when going with a large company of people to seek a settleent in Macedonia, was commanded by an oracle to take the goats for his uides to empire. He accordingly followed a herd of these creatures, that astened to shelter themselves from a violent storm; but the country being pen, and neither rocks nor woods within reach, they went on till they came Egessa: at that place, accordingly, Coranus halted, and commenced the uilding of a city: he made the goats his standards, and called the city Egeæ, or the goats' town; and the people Ægeadeæ, or the goats' people. he city, thus singularly founded, became in after years the burying-place f the Macedonian kings; and moreover, Alexander the Great, mindful of s singular origin, gave to his infant son, who was born there, the name of lexander Ægus, or the son of the goat.

We have thought it desirable to give the letters of the Greek alphabet, s they continually occur on celestial charts:—

ALPHA	α	IOTA	ι	RHO	ρ
BETA	β	KAPPA	κ	SIGMA	σ ς
GAMMA	γ	LAMBDA	λ	TAU	τ
DELTA	δ	MU	μ	UPSILON	υ
EPSILON	ε	NU	ν	PHI	φ
ZETA	ζ	XI	ξ	CHI	χ
ETA	η	OMICRON	ο	PSI	ψ
THETA	θ	PI	π	OMEGA	ω

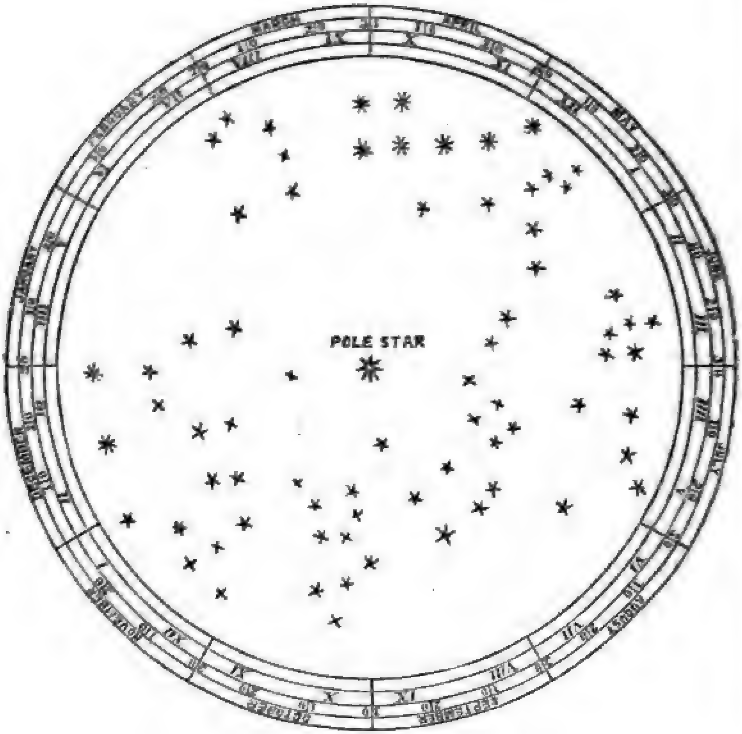
CHAPTER IV.

APRIL.

"How beautiful the scene! Ten thousand stars
Move in the heavens at their 'own free will.'
The moon, her higher destiny to fill,
Rideth resplendent as the shield of Mars!
The sea beneath is tranquil as a child
Hush'd by caresses on its mother's breast,
There sleeping like a statue that doth rest,
By dreams unmoved." EDWARD MOXON.

APRIL is a charming month for star-gazing; the nights are less old and frosty than in March, but the constellations sparkle with equal eauty.

Look towards the Pole-star, and hold that part of the starry circle ppermost which is opposite to the beginning of April. You will readily erceive that such stars as are delineated on the upper portion appear not ar from the zenith, or nearly overhead; others, on the lower part, seem erging on the horizon; those to the right occupy situations eastvard; those on the left, positions westward, though differing in elevaions. At a considerable height above the Pole-star are the two pointers



of the Great Bear; and at nearly an equal distance beneath shines the constellation Cassiopeæ. Westward of the Ethiop queen is stationed Perseus, of which Algenib is the chief star; and both are at only a small elevation above the northern horizon. Eastward of Cassiopeia is Cepheus, presenting a kind of square or rhombus, formed of four stars, two of the third and two of the fourth magnitude, among which Alderamin is the most conspicuous. Stars further to the east, and holding a more elevated position, mostly pertain to the constellation Draco, or the Dragon, coiling at apparently a short distance from the Pole-star; and nearly due east is the star Etanim, belonging to this constellation. Westward, or on the left hand, and almost opposite to Etanim, are bright stars composing the constellation Auriga. Among these Capella and Alajoth shine conspicuous: the former appears nearly W. by S. from the Pole-star, at a considerable elevation; with Menkalina, pertaining also to Auriga, and beaming eastward. The chief stars connected with the Great Bear, although figured as guides amongst the starry glitter, are too well known to render any further description necessary.

Such are the prominent constellations which diversify the northern part

of the heavens about the beginning of this pleasant month, when stars and flowers delight equally the astronomer and botanist. There are also several brilliant stars of the first magnitude which require notice. Look, therefore, E. by S., and the beauteous star Arcturus may be seen in the constellation Boötes, about midway between the horizon and the zenith: north-east appears a star of not less beauty—Vega or Lyra, elevated 20° above the horizon, in a direction nearly opposite Capella. Deneb, pertaining to the Swan, shines farther north, and at a lower elevation than the Lyre. Midway between the western horizon and the zenith, yet verging to the west, Castor and Pollux recall the thoughts to a period of remote antiquity. Further down, and nearly on the horizon, almost due west, are Betelgeux and Ballatrix, in the shoulders of Orion, who has partially descended below the horizon. South-west, and midway between Pollux and the horizon gleams Procyon, a star of the first magnitude, in Canis Minor, or the Lesser Dog.

With reference to such among the heavenly luminaries as are depicted in the circle, it must be held in mind that they are perpetually visible, leading a circling dance above the horizon, and having the Pole-star as their centre.

It is likewise desirable to remember that, as the observer is supposed to be in 52° north latitude, all stars within 52° of the pole never descend below the horizon, varying as the weeks roll on; at one time seemingly above the pole, and even near the zenith; at another, even below that point, and verging near the northern horizon. When riding high, they appear to move from east to west; when otherwise, from west to east. Such as are near the Pole-star describe small circles; such as take a wider range necessarily describe larger ones; but their periods of apparent revolution are the same—that is, 23h. 56m. 4sec.

Such stars as we have thought it desirable to represent are prominent and obvious in the heavens; others might have been introduced, but they would tend to perplex beginners; and in order most readily to estimate apparent distances between the stars, as also from the horizon, it will be found a great assistance to bear in mind that the space between the two pointers comprises exactly 5°, and between Dubhe, nearest to the pole, and the Pole-star, 29°.

We recommend our readers to make a pasteboard circle, as the one we have pictured, though much larger, and copy the stars thereon; to obtain, also, a square board, or piece of thick pasteboard, and form a larger circle of months and days, the lesser circle being affixed to the larger, about the centre, so as to move readily. An astronomical clock may be thus obtained for pointing out the hours of the night, and showing the positions of the circumpolar stars at any hour of the day or night. The idea is suggested by a most ingenious planetarium, to which we are indebted for much instruction.

Our last two chapters spoke concerning the mythological history of some distinguished constellations; we shall now refer to the phenomena of double stars in each, as discovered by the aid of telescopes, premising our remarks by saying that little was known with regard to this interesting subject till Sir William Herschel commenced his extensive observations on the sidereal heavens. Astronomers were, indeed, previously aware that double stars held an interesting place among their brethren, but they had not extended

their discoveries; they contented themselves with ascertaining their existence, and noting six or eight in their charts. When, however, the thoughts of Sir William Herschel were directed to the subject, and his telescope swept the starry heavens, no less than five hundred double stars were added, having their situations and relative positions distinctly marked. The son of this illustrious astronomer discovered many more: his unwearied labours, with those of Sir James South, produced an additional list of three hundred and eighty. Subsequently Sir J. Herschel formed a distinct catalogue of 3,300 double and even triple stars, the result of his own observations, accompanied with precise measurements of their distances and angles of position; and Sir James South identified four hundred and eighty, the result also of his own labours. Since then further discoveries have increased their numbers. The celebrated astronomer, Struve, makes mention of no fewer than 3,000 double stars, in the progress of identifying which he examined about 120,000 of those sparkling luminaries which gem the vault of heaven.

The southern hemisphere reveals two hundred and fifty stars of the same description, according to the testimony of Mr. Dunlop; and during a late residence at the Cape of Good Hope, Sir James Herschel added considerably to their list. It is, therefore, conjectured that 6,000 have been made the subject of accurate research.

Connected with the mention of double stars is that important discovery which realizes the fact of a progressive and regular change, bearing in some stars chiefly on their position, in others on their distance, and which results from the smaller star revolving round the larger in an elliptical or circular orbit, although occasionally both stars revolve around some central point. Those who narrowly observe the heavens by aid of a high magnifier may readily ascertain the fact of a revolving motion in such stars as are called double. At one time the satellite or smaller star disappears, in consequence of becoming obscured while passing behind the other, as Jupiter or Venus is occasionally invisible when on the opposite side of the sun, or the satellites of Jupiter, if similarly circumstanced with regard to that planet. Three stars have occasionally been seen revolving about a common centre, and even four or five.

The orbits in which one star circles round another are generally elliptical, similar to the path described by the earth and other planets when revolving round the sun, as also those in which the satellites of Jupiter, Saturn, and Uranus perform their revolutions. These orbicular motions are either retrograde or direct, or in the same direction as the movements of our own planets; and very curious is the fact with regard to the star π Serpentarii, in common with many others, that the revolving star appears to move in a straight line, and to oscillate on either side of the larger star, around which it revolves in a manner similar to the satellites of Jupiter, which pass apparently from one side to the other of the planet in nearly straight lines—an effect resulting from the plane of their orbits being nearly in a line with the eye of the observer. When Sir William Herschel first directed his attention to the subject of double stars, the two stars to which we have referred were distinctly separate. At the present time the lesser star is so completely projected on the other, that even the most powerful telescope cannot reveal any separation; and why? Because one star is passing across the disc of the other, and will not again be visible till after the lapse of many years.

In our next chapter we shall instance several binary, or double stars, belonging to such of the constellations as have already been regarded in a legendary or historic point of view.

Taurus, one of the zodiacal constellations, pertains to this month, and may readily be discovered near Perseus and Orion. It is needful to remark that the sign or figure, as represented in the earliest charts, and retained to the present day, is merely the front portion of the animal.

CHAPTER V.

MAY.

"May! majestic child of heaven,
To the earth in glory given;
Verdant hills, days long and clear,
Come when she is hovering near.
Stars, ye cannot journey on
Joyously when she is gone."—DAVYTH AP GWILYM.
(*Fourteenth century.*)

THE zodiacal light is rarely visible in this country, excepting during the months of April and May, when it may be seen in clear and cloudless evenings soon after sunset, or, at the opposite season, before sunrise. It resembles a cone of light extending from the horizon obliquely upwards, and is conjectured to be a rotating ring of finely-divided or nebulous matter, situated, perhaps, between the orbits of Venus and Mars, but certainly extending beyond that of the earth.

Though faint and dimly defined in the northern regions of the globe, and totally distinct from any atmospheric meteor or aurora borealis, those who have resided in the zone of palms must ever retain a pleasing remembrance of the mild radiance of this beautiful phenomenon, which rises pyramidically, and illumines a portion of the unvarying length of the tropical nights. Humboldt speaks of it with enthusiasm, as occasionally shining with greater brightness than that of the Milky Way, near the constellation of Sagittarius; and this not only in the dry and highly-rarefied atmosphere of the Andes, at elevations of thirteen or fifteen thousand feet, but also in the vast grassy plains of Venezuela, and on the sea-coast, under the ever-clear sky of Cumana. The same great traveller speaks of the zodiacal light as a phenomenon of unrivalled beauty, more especially when a small fleecy cloud floats across it, and seems as if detached from the illuminated background. A passage in his journal, during a voyage from Lima to the west coast of Mexico, especially refers to such a beauteous incident, when night after night the zodiacal light appeared with a magnificence he had never before seen; and, judging from the brightness of the stars and nebulæ, it was evident that the transparency of the atmosphere in that part of the Pacific Ocean which lay between 10° and 14° of north latitude must have been extremely great. Humboldt delighted to observe the glorious aspect of the heavenly luminaries; he mostly slept on deck, and watched with intense interest those celestial phenomena which are especially conspicuous in the southern hemisphere. During three whole nights, from the 14th to the 16th of March, and during a very regular interval of three-quarters of an hour after the sun had set, no trace of the zodiacal light was visible,

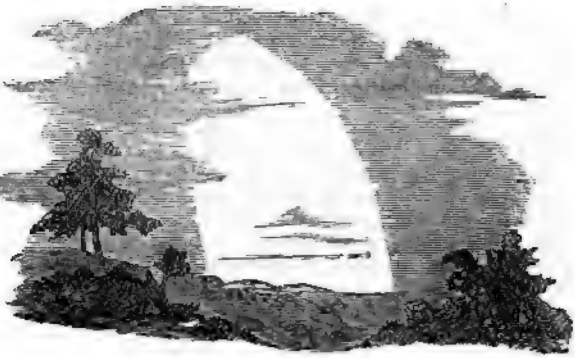
although the darkness was great; but scarcely had an hour elapsed before it became suddenly apparent, extending in great brightness between Aldebaran and the Pleiades, and on the 18th of March attaining an altitude of 39° 5'. Long, narrow clouds, scattered over the lovely azure of the sky, appeared at a small height above the horizon, as if in front of a golden curtain; somewhat higher up were ranged other clouds, varied with changing tints of the greatest beauty, and presenting the appearance of a second sunset. Nor was the phenomenon itself of that mild radiance which seems to possess little reality; its diffused light equalled that of the moon in her first quarter; moreover, a mild reflected glow was visible in the east. Floating over the waters of the Pacific, with measureless depth beneath, and immensity above, it seemed impossible to close the eyes in sleep while the light of which we speak continued to illumine the heavens; it suddenly became visible, but did not long continue; towards ten o'clock it gradually diminished in lustre, and at midnight scarcely a trace remained.

While exploring also the tropical regions of South America, the same enterprising traveller noticed with astonishment variations of intensity in the zodiacal light. Having passed his nights during several months in the open air, and under a serene sky, on the banks of great rivers, or in the midst of vast savannahs, he had frequent opportunities of carefully observing it; at one moment shining with a steady light, and then seeming to fade away; again suddenly re-appearing in full brilliancy, with an undulating motion. Madame Marian, who watched this beautiful phenomenon with the deepest interest, mentions having once observed a reddish tinge connected with it. Processes, therefore, were conjectured by Humboldt to be going on in the nebulous ring itself; or else that, although in the lower region of the atmosphere, condensations were taking place at a higher elevation, which modified the transparency of the air, or rather its reflecting power, in some peculiar and unknown manner.

Strange it seems that such an attractive spectacle should have failed to excite the attention of astronomers before the middle of the seventeenth century; or, to borrow the language of the author of *Cosmos*, "that it should have escaped the observant Arabs in ancient Bactria, or the Euphrates, and in southern Spain." Such, however, is the fact; and although, even in this our obscurer sky, the zodiacal light is distinctly visible in the beginning of spring, after evening twilight, above the western horizon, and at the end of autumn, before the dawn of day, as if heralding the sun's rising in the east, the earliest description of it is contained in Childrey's *Britannia Baconica* of the year 1661:—"I have observed," said he, "several years together, when twilight hath almost deserted the horizon, a plainly discernible ray of the twilight striking up towards the Pleiades, and seeming almost to touch them; but what the cause of it in nature should be, I cannot yet imagine, but leave it to further inquiry." The same phenomenon was farther noticed by Dominic Cassini about twenty years later.

Humboldt mentions also that most probably the remarkable light, rising pyramidically from the earth, as described in an ancient Alex. manuscript now in the royal library at Paris, and seen in the eastern part of the sky during forty nights successively from the high table-land of Mexico, was that same beauteous light which is now visible in the temperate zone.

This phenomenon, doubtless of primeval antiquity, but first discovered in Europe by Childrey and Dominic Cassini, cannot be regarded as the lumi-



nous atmosphere of the sun itself; it is rather attributable, as already mentioned, to an extremely oblate ring of nebulous matter, revolving freely in space between the orbits of Venus and Mars. No certain judgment can be formed concerning the true dimensions of the supposed ring; but, according to the opinion of Humboldt, the nebulous particles of which the ring consists, and which revolve around the sun according to the same laws as the planets, may either be themselves luminous, or may reflect the solar light. The first supposition is not inadmissible: even a terrestrial fog showed itself, about the middle of the eighteenth century, at the time of the new moon, and in the middle of the night, so phosphorescent, that objects could be distinctly recognized at a distance of above six hundred feet.

Thus far we are indebted to the accurate observation of Baron Humboldt in his *Physical Description of the Universe;* and, before dismissing this portion of our subject, we earnestly recommend our readers to watch carefully for the appearance of the wonderful phenomenon, which few, perchance, have seen.

Several of the more brilliant constellations have disappeared. Orion has sunk beneath the western horizon, and among the stars which held such prominent stations during the past months, Betelgeux is alone visible. Aries is seen no longer; the Pleiades and Aldebaran, Caput Medusa and Taurus, verge on the borders of the north-western horizon; and Sirius is completely set. Southward gleams the Hydra's head, with Alphard, its chief star; and considerably to the west of Alphard, though nearly at the same altitude, are Canis Minor and Procyon. Castor and Pollux may be readily discerned northward of Procyon, nearly midway between the zenith and the western point of the horizon. Nearer the north-western horizon than the zenith, though widely separate, is Capella. Cassiopeia has descended from her elevated position, and taken a humbler place near the northern quarter of the heavens. The Great Bear, on the contrary, shines not far from the zenith; his two pointers seem directed downwards to the Pole-star. Regulus is about 22° west of the meridian, at a commanding elevation; Denebola, pertaining also to the Lion, is on the meridian, somewhat higher than Regulus; Arcturus looks down from his place in heaven, in the direction of E.S.E.; and 26° to the north-west of this bright star is Cor Caroli, near the zenith. You

may readily discern the Northern Crown due east, midway between the zenith and the horizon; and α Lyræ shines in perfect beauty. Near the north-east, about 23½° above the horizon, in the N.N.E. quarter, gleams the Swan; and one of its chief stars, Denebola, is about 14° above the horizon. Draco is somewhat higher—at least 20° above α Lyræ, and nearly in the same direction.

Now look towards the eastern and south-eastern portions of the sky. Virgo, Libra, Taurus, Poniatowski, Serpentarius, and Hercules are all visible. Spica Virginis, a bright star of the first magnitude, is 24° above the horizon, occupying a direction S.S.E.; it is 35° south-east of Denebola, and nearly the same distance S.S.W. of Arcturus: these three stars form a large equilateral triangle, pointing to the south. A similar triangle next engages the attention, inclining northward, and consisting of Arcturus, Denebola, and Cor Caroli. Direct your attention, in the next place, nearly due west, at a small elevation above the horizon. Ras Algethi, chief star in Hercules, beams there; as also Ras Alhague, 5° distant, in the head of Ophiuchus—the former is the brightest. Southward of Serpentarius, and eastward of Virgo, shines Libra, of which the two most prominent stars are of the second magnitude; the one named Zubeneschamali, 21° eastward of Spica Virginis, but at a lower altitude; the other Zubenesgemabi, about 9½° higher, towards the north-east, although occupying a position in the south-east quarter of the heavens, and slightly elevated above the horizon. Serpentarius extends between Corona Borealis and Libra; its principal star, Unuk, is of the second magnitude, but is readily discerned by observing that it is nearly in the middle, between two lesser stars, the lower being 2½°, the upper 5½° distant; moreover, it is in a direction E.S.E., about 24° above the horizon.

This pleasing constellation, although containing fewer stars than many others, is yet of considerable importance, and may be readily distinguished. In order, therefore, to facilitate its recognition, the learner will do well to observe that when Gemini is on the ecliptic, the back of the right-hand figure is towards Cancer, and the face of the left towards Taurus. The Lynx appears as if galloping over them, the hinder feet coming near the Crab. Auriga approaches the right-hand figure; the head of the Unicorn is beneath their feet, near which is seen Orion, with Canis Minor immediately behind him.

The orbit of the earth, or the apparent circle described by the sun in his annual course, passes through the midst of this constellation, from the 21st of June till the 23rd of the following month, but the brightness of the solar rays renders the stars of which it is composed invisible. At other times the two brilliant stars demoninated Castor and Pollux shine pre-eminent: the first, the northernmost of the two, is a star of the first magnitude; the second, situated a little to the south-east, is considerably less brilliant. Castor is a double star, the smaller being invisible to the naked eye, yet revolving around the larger with a slow motion. About 20° south-west of Castor and Pollux are three small stars, nearly in a straight line, and about three or four degrees apart. The southernmost lies parallel with Pollux and the star *Betelgeux*, pertaining to Orion, but somewhat nearer to the former than the latter. These stars form the feet of the Twins.

We have already mentioned that the division of the zodiac into constellations originated in Chaldea, and that the design of such an important

division was mainly to point out distinctive periods of business and of profit. Hence the Ram designated the first portion of the vernal season; Taurus, the second; and Gemini, or Twin-kids, the third. In Chaldea, doubtless, originated most of those divisions which have descended to the present age; from thence they passed into Egypt; and, although no longer conveying the meaning that was intended, and which bore expressly on rural occupations and changes of the seasons, they were retained by Egyptian astronomers, in order to prevent the inconveniences of needless innovations. This is evident, because Aquarius, the watery constellation, which pours the rains of winter from his flowing urn, and is symbolic of cloudy skies, has nought to do with Egypt; for in that country it never rains, and winter is the finest season of the year.

The Greeks, that imaginative people, who delighted in the wildest legends of bygone days, regardless of the important facts which yet they often darkly hinted, assigned some poetic legend to most of the constellations, and claimed the Twins as especially originating with themselves. Castor and Pollux, they said, are immortalized in the heavens; the love and friendship of those heroes are worthy the imitation of all brothers; their innumerable exploits and deeds of heroism may well be inscribed among the stars. Some there were who preferred other names for those twin stars, calling them Hercules and Apollo; others, again, gave them the appellation of Triptolemus and Sasion; the first, because he was rendered serviceable to mankind by Ceres, who taught him to sow corn and make bread; the other, because, reigning over Attica, he diligently employed himself in agriculture. The names thus given have not, however, been associated with the Twins in celestial charts.

Sir Isaac Newton, who considered the history of constellations with reference to the exploits of ancient heroes and the progress of civilization, assigns the era of Castor and Pollux, in common with many others, to the time of the Argonautic expedition. He mentions that Muscæus, celebrated as having constructed the first sphere ever seen in Greece, was father to Orpheus, one of the Argonauts; and he infers that very many of the constellations referred in their history to incidents connected with that memorable voyage. Others had, doubtless, an origin in periods still more remote, and were unconnected with aught of Grecian imaginings or history, being evidently associated with the occupations of rural life. Among these, the constellation Virgo, though equally the theme of poets and of painters, was originally no other than a sunburnt maid who wrought in the fields; her spike of ripening corn betokens the approach of harvest; and thus is she depicted in Egyptian charts of the highest antiquity.

No obvious changes are apparent in the starry heavens. Those who delight in observing the progress of the constellations, moving in silent majesty through the vault of night, discern at first only a vast concave, spangled with innumerable stars, differing in brilliancy, but apparently without order or arrangement. Those who compare them with a celestial chart, discern, on the contrary, that order, "Heaven's first law," is equally observable in the heavens as on the earth; but the astronomer alone, who, with the assistance of a powerful telescope, passes sleepless nights in contemplating the glory of the stars, can point out with certainty the changes that occasionally take place among them.

Hipparchus, a celebrated astronomer of Rhodes, who flourished about 120 years before the Christian era, first noticed the appearance of a new star.

After searching carefully the records of astronomers who had preceded him, and finding no mention of it, he began to form a catalogue of all such stars as were within his range of vision, noting the place and apparent magnitude of each, and thus forming a first list of the heavenly luminaries.

About 130 years after the coming of our Lord, a new star appeared near *a* Aquilæ, or Altair, in the constellation of the Eagle, but only as a transient, though brilliant, visitor, continuing about three weeks, and then entirely disappearing. In the ninth century a sparkling luminary became visible in the fifteenth degree of Scorpio; subsequently another, between the constellations of Cepheus and Cassiopeia; but no astronomic particulars are recorded respecting them.

We owe to the sudden appearance of a beauteous star in Cassiopeia the determination of Tycho Brahe to become an astronomer. He was returning to his house about ten o'clock, when his attention was attracted by a crowd of country people, all of whom were gazing upwards with acclamations of surprise. "What are you looking at?" said Tycho Brahe. "At a great light in the heavens," they all exclaimed. And truly the sight was wonderful. A new star, dazzlingly white, and yet with a slight bluish tinge, so bright as to cause his staff to cast a shadow, surpassed in brilliancy Lyra and Sirius; it appeared even larger than Jupiter, and superior to the planet Venus in its greatest lustre. Day after day the same star was visible in the heavens; and at night might even be discerned when light fleecy clouds obscured all others of the celestial orbs. Thus the stranger star shone on for about three weeks, when its lustre gradually diminished from a degree of brightness superior to that of a star of the first magnitude to one of the sixth, after which it entirely disappeared, and was no more seen. Nor less curious is the fact, that during the sixteen months of its occupying the same position it was subject to considerable changes of colour; at first shedding a white and brilliant light, then becoming yellowish; next in hue approaching that of Mars; lastly, of a pale livid light, like that pertaining to far-distant Saturn. The longitude of this star, as determined by Tycho, was 90° 17′, and 53° 45′ of north latitude.

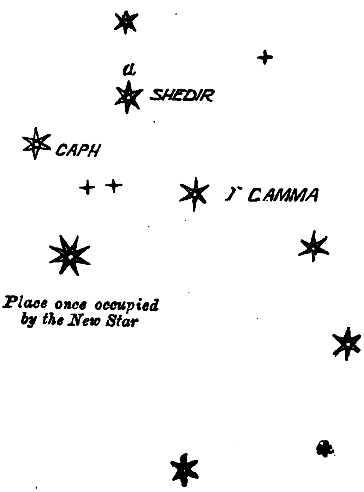
In our second representation the large star towards the left points out the place occupied by the new star among those of Cassiopeia.

A new star appeared also in the beginning of the seventeenth century, near the heel of the right foot of Serpentarius. Astronomers agreed that it was perfectly round, resembling one of the fixed stars, and both in vividness and lustre exceeding even the one mentioned by Tycho Brahe; being at the one time yellow, at another orange, then red or purple, but most commonly it was of the purest white, when slightly elevated above the horizon. Gradually, at length, its transient light began to fade, and those who watched its waning hue from week to week report, that about a year and one month elapsed from the period of its sudden and brilliant appearance to its being no longer visible.

CASTOR AND POLLUX.

None of these transient visitors have ever reappeared, and the places

which they occupied still remain a blank. A strange mystery seems to hang over such wonderful phenomena —none have solved it, or satisfactorily accounted for the appearances of such engrossing interest.



Place once occupied by the New Star

DOUBLE STARS.

Andromeda (Fig. 1) presents a double star in her left foot, called Almaack; the small star is of a fine greenish-blue tint, the larger of a reddish-white. United, as regards the unassisted eye, they form a star of the second magnitude, about 42° of north declination, passing the meridian early in December, about half-past ten in the evening, and about 10° southward of the zenith.

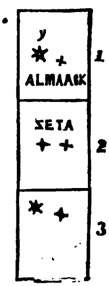


Fig. 2 represents Zeta, in the sign Aquarius, or the Water-bearer. The kindred stars are nearly equal in apparent size; they are about one diameter and a half apart from each other, and are both of a whitish colour, forming together a figure resembling the letter Y. They come to the meridian at nine o'clock in the evening, about the 15th of October, where they appear as stars of the third magnitude.

Fig. 3. This figure represents the Pole-star; its attendant is very faint, and requires an accurate telescope of considerable power. The Pole-star itself is white, the secondary of a ruddy hue, and is distant 17″, or about three or four of its diameters.

A beautiful star of this description pertains to the Great Bear; it is called by astronomers *Zeta*, or *Mizar*, and may be noticed about the middle of the tail. Another, marked ξ, is in the right foot of the same constellation: in this the two component stars revolve around each other in about sixty years—consequently nearly a whole circuit has been performed since its discovery at the latter end of the last century. The lesser completes its revolution in fifty-eight years, and is, therefore, conjectured to move at the rate of two millions four hundred and seventy-one thousand miles every hour, exceeding by eighty-five times the velocity of Mercury, the swiftest-moving planet of our system.

Another and most interesting subject for contemplation is the contrast afforded by the double stars in point of colour. According to the minute observations of Sir James Herschel, a considerable number exhibit the beautiful and curious phenomena of contrasted hues. When this occurs the larger star is usually of a ruddy or orange tint, while the smaller is either blue or green—probably in virtue of that general law of optics, which provides that when the retina of the eye is excited by any bright-coloured light, feebler lights, which, if seen alone, would look nearly white, appear

for the time as coloured with the tint complimentary to that of the brighter. Thus, for instance, if a yellow light predominates in the light of the most conspicuous star, that of its attendant in the same field of vision assumes a bluish tinge; whilst, if the tint of the first verges to crimson, that of the second exhibits a tendency to green, or even becomes a vivid green under favourable circumstances. The former contrast is beautifully exhibited by *Iota Cancri*, the latter by *Gamma Andromedæ*, both of which are fine double stars. Should, however, the coloured star be less bright than its companion, the other will not be materially affected.

Were it possible to look down from some unimaginable height on those sparkling luminaries which shine far above our heads, with visual organs adapted to such a comprehensive view, what glories would be revealed! for not even a bed of tulips affords more exquisite diversity of colour than the stars of which we speak. Two luminaries, a red and green, or blue and yellow, might be seen revolving round a common centre, presenting grateful vicissitudes of day and night, in which a beauteous tinge of red or green alternates with light or darkness, as one or other of the varied orbs ascends above the horizon, or sinks below it. Insulated stars of a red colour, nearly resembling that of the *Lobelia fulgens*, would appear at intervals, but never a decidedly green or blue star unassociated with a companion brighter than itself. One planetary hemisphere might appear illuminated with a yellow sun, while the other was shone upon with emerald rays; nay, more—both suns might occasionally adorn the heavens, shedding their blended hues and contrasted colours over a wide surface. According to the courses of the planets around their central point would such effects be variously modified, and become productive of almost perpetual variety. A dazzling red luminary might rise above the horizon, while another of the softest emerald green was about to set; and when both were absent, innumerable stars would glitter in the immensity of space.

CHAPTER VI.

JUNE.

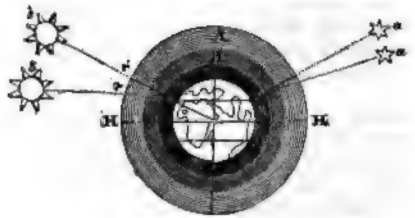
"I love thee, Twilight; while thy shadows roll,
The calm of evening steals across my soul,
Sublimely tender, solemnly serene,
Dear as the hour, enchanting as the scene."

We know that light is derived from the sun—that by the aid of this most admirable gift of the Creator we behold His glorious works, and are able to transact the affairs of life. We know, also, that the grateful vicissitudes of day and night depend upon one-half of the globe being turned to or from the great source of light to our solar system. Now, in order to prevent a sudden transition from brightness to an obscurity that would immediately involve us in darkness, to which neither the presence of the stars, nor even of the moon could reconcile, we are surrounded by an atmosphere which ministers to the world by reflecting the light of the heavenly bodies, and refracting the sunbeams.

Twilight, therefore, is its natural result, moderating the otherwise instant transition from light to darkness, and even shortening the long and dismal night of the frigid zone.

The subject is one that well deserves a brief elucidation, and may be thus explained.

A ray of light, passing through the atmosphere, moves in a straight line so long as the atmosphere remains of the same density; should, however, any change occur in this respect, the rays become bent, and this bending is called *refraction*. Persons unacquainted with the subject might naturally conjecture that the aërial element by which we are surrounded would be the same throughout; but such is not the case. The light elastic fluid termed atmosphere, not $\frac{1}{800}$th part so heavy as water, presses in its upper portions on such as are next the earth, and causes them to become comparatively dense or compact. This compression necessarily imparts to the lower atmospheric portions a greater power of refracting or bending the rays of light than is possessed by the upper. Hence it necessarily follows that the atmosphere, being more dense or compact at the earth's surface, gradually becomes lighter, until it ceases to disturb the direct progress of a ray of light. Now, in order the more readily to observe the gradual turning aside or bending of a ray, so as to form a curved line, refer to the preceding engraving, and notice especially the decreasing density of the atmosphere at different elevations above the earth. Suppose HH to be the horizon of an observer, and S to be the sun, already set, the ray S*r* will proceed in a straight line from its own glorious source, until it reaches the atmosphere A, at which point it begins to bend; but were the medium through which it has to pass of the same elasticity and lightness throughout, the ray would continue in a right line, though not in the same direction as at first. This, however, is not the case; the density of the atmosphere, as already mentioned, ncreasse towards the earth; the ray becomes more and more bent on entering the different mediums B and C, and the observer, standing on the earth's surface at O, receives the refracted ray in a curved line. As, however, he can only see an object in straight lines, he seems to be shone upon by the sun's rays at *r*, while the image of the sun is perceived by him at S.



EFFECTS OF REFRACTION.

It is consequently evident that the heavenly luminary is never seen in his true place, except when in the zenith, refraction having no effect upon a vertical ray; moreover, that refraction is greatest at the horizon, and that it gradually decreases as the atmosphere becomes more rarefied. The same remarks hold good with regard to the stars, and star *a* is seen at *a* by an observer stationed at *o*; but being higher up, the rays are not so much refracted as in the case of the sun. The altitude of those beautiful stars which nightly adorn the heavens seems greater, therefore, than it is, in proportion as they are contemplated at higher or lower elevations.

Many curious and beautiful effects result from this turning aside of the rays of light. When, for instance, we seem to see the orb of day imme-

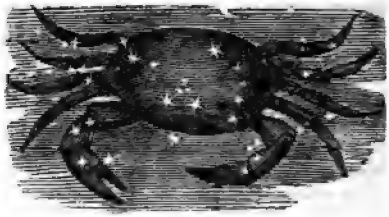
diately above the horizon at sunrise and sunset, such is not actually the case; but the effect proceeds from the bending of his rays towards the part where we happen to be. Again, the density of the atmosphere occasions the sun and moon to appear larger than when their rays descend to us less obliquely; and owing to the difference in density which often prevails in a small space, the lower and upper portions of the discs of the sun and moon assume a compressed or oval form.

When the former appearance is presented by the moon, about the end of the second and third quarter, it is generally indicative of rain or wind. The boat-like form is, nevertheless, extremely pleasing, when seeming to float through trackless ether, or urging its way amid innumerable clouds, light, fleecy, and fantastic.

Such is the supposed cause of twilight; and yet, to borrow the remark of Humboldt, the extraordinary lightness of the nights during the summer of 1831, occurring in the latitudes of Italy and northern Germany, when small print could be read at midnight, was in manifest contradiction to all that had been taught on the theory of twilight, and the height of the atmosphere.

A few additional stars are added to those of last month; but twilight, at this season, is too strong to admit of noticing them very particularly, more especially as they have not risen far above the horizon.

The sun enters this interesting constellation on the 21st of June, the first day of summer, the longest in the northern hemisphere, mid-day at the North Pole, and midnight at the South.


CANCER.

Macrobius, who ingeniously explained the origin and intent of all such figures as were anciently associated with the constellations, considers them as part of the hieroglyphic language which the ancients inscribed on the heavens. They placed, said he, the Crab and Goat, Cancer and Capricorn—not by chance, nor yet without design—at the two corners of the sun's course, but at once to mark the points, and to convey the knowledge of certain celestial phenomena. When the sun arrived at an assigned limit, they perceived that he began to move backwards, and to descend obliquely; and in order to mark the place where this occurred, they took note of the stars that shone in its vicinity; and for the purpose of rendering these familiar to the mind, they associated with them different kinds of living creatures. The Crab, which moves backward and obliquely, afforded an apt symbol of the sun's retrograde movement. And although the constellation of the Goat had reference to pastoral occupations, it also marked the opposite natural barrier of the sun's progress, that part of the ecliptic where, having quitted his lower path, he begins to ascend higher and higher. The wild goat, therefore, an animal which delights in climbing the loftiest mountains, was selected as the figure under which to arrange a symbolic constellation.

The "neighbour stars" that surround the Crab are those of the Lynx, the Lion, and the Twins, the Unicorn, the Little Dog, Hydra, and the Lesser Lion. The Greater Lion is stationed immediately before it. Hence it happens

that the harmless Crab, and the monarch of Libyan wastes, appear as if looking earnestly at each other; that the hind feet of the Lynx come very near to the side of Cancer; that the Twins are close behind; and that, further, Unicorn, the Dog, and Hydra form a line between the lower portion of the Twins and Lion.

Cancer exhibits a group of stars called Præsepe, or the Bee-hive, or rather a cluster of very minute stars, not separately distinguishable by the naked eye, but sufficiently luminous to be seen as a nebulous speck, somewhat resembling the nucleus of a comet, and for which it has occasionally been mistaken by casual observers. Præsepe is situated in a triangular position, with regard to Castor and Procyon, or the Little Dog: a line drawn from the latter in a north-easterly direction meets with this nebulous cluster at the distance of twenty degrees, and if extended in a north-westerly direction from the same, meets Castor at an equal distance, forming, altogether, nearly a right angle, of which the angular point is in Præsepe. It may also be discovered by means of two stars of the fourth magnitude, lying one on either side, at the distance of two degrees.

When contemplated with a three-and-a-half-feet achromatic, and a power of ninety-five, it is scarcely possible to imagine any kind of celestial scenery more brilliant or more beautiful. Fifteen or twenty of the most conspicuous among its clustering stars present admirable configurations; one is nearly an equilateral triangle; another, an isosceles; a third resembles a cone; a fourth presents parallel lines. In more than two instances three bright stars appeared in a straight line, similar to the belt of Orion, while a considerable number were extremely minute.

The word "nebula," applied by astronomers to denote certain fixed and apparently whitish clouds in the heavens, literally signifies a cloud or mist, consisting of innumerable stars, so thickly studded together that their combined light presents the thin luminous appearance by which they are distinguished. Sir William Herschel conjectures that however widely dispersed, they yet encompass the whole starry sphere of heaven, like the Milky Way, which is undoubtedly composed of fixed stars. He mentions that nebulæ are more general in some parts than in others; that spaces in their vicinity are often starless; and that luminous clouds, or mists, are more frequently among stars of considerable magnitude than among those of minor importance.

Various forms and classes may be noticed, although reducible into two great divisions—viz., such as are composed of countless stars, though discoverable only by the aid of powerful telescopes, and such as the highest magnifiers have not been able to reveal otherwise than as merely luminous clouds. In former times about one hundred nebulæ were known to astronomers; since then the unwearied exertions of Sir William Herschel have brought to light at least two thousand more. Their different places were afterwards computed from his observations, and arranged in a catalogue, in the order of right ascension, by his sister, Caroline Herschel, a lady distinguished for her astronomical knowledge and discoveries. Her illustrious nephew, Sir John Herschel, added five hundred nebulæ to those discovered by his father, as also the same number in the southern hemisphere, among which the Magellanic clouds are the most beautiful and conspicuous.

These dim and wondrous nebulæ, whether containing a bright assemblage of glorious stars, or whether bearing only the appearance of a far-off cloud,

are often most singularly varied. Herschel speaks of several as presenting equally eccentric and curious forms. Among these is one resembling a luminous hour-glass, surrounded by a thin, hazy atmosphere; another, consisting of a nucleus, bright and circular, having a nebulous ring; a third, faint and branching, of a milky whiteness, and diversified with bright spots.

A remarkable nebulosity appears in the constellation of Orion, discernible without the assistance of a glass, and occupying a middle distance in the sword. Huggins observed the appearance, and remarked concerning it that astronomers had noticed three stars close to each other in the sword, but that when he examined the middlemost with a telescope he readily perceived twelve other stars; three that nearly touched each other, and four that seemed to twinkle dimly, as through a cloud. This nebulosity exhibited an indefinite foggy appearance, brighter, yet more diffuse when a telescope was used; but the whole power of Herschel's forty-feet reflector could not resolve it into distinct stars. Nothing, however, deterred, Huggins continued to observe it with the greatest interest; and at length, having perfected his forty-feet telescope, discovered that it possessed such a magnitude and brilliancy as fully to warrant him in believing that it was the nearest of its brethren, and consequently likely to afford much valuable information. Apparently it was composed of little flocky masses, or wisps of clouds, adhering to small stars at its outskirts, and could not, perhaps, be more aptly described than by comparing it to a curdling surface strewed over with small locks of wool, or the breaking up of a mackerel sky, when the clouds assume a wavy appearance. Whatever the filmy mass might be, its dimensions were enormous. "We know not," wrote the astronomer, "what the immense looming mass portends; time may, however, develope it, and, with the passing on of years, facts may be elicited that will astonish the world."

NEBULOSITY IN ORION.

And so it has been. The telescope of which we are about to speak has discovered the revolution of this stupendous nebula. When Dr. Nichol visited Parsonstown he saw the nebula through its mighty tube. It was the first time that the grand instrument had been directed towards that mysterious object, and though Lord Rosse warned him that circumstances connected with its examination did not admit of a final conclusion with regard to existing theories, the narrator went with breathless interest to its inspection. Not the slightest trace of a star was discoverable: "looming unintelligible as ever, appeared the nebula; but how brilliant its brightest portions! How broken the interior of its mass! How innumerable the streams that seemed attached to it on every side! How strange, especially a large horn northward, rising in bold relief, amid the darkness of the night, like a cumulous cloud!" Truly had Lord Rosse remarked, that one observation would not suffice with regard to a number of sparkling points, small as those of a needle, nearly as close as grains of sand, the more especially when any sudden gust of wind, or momentary irregularity in the instrument, might cause the light of each to mingle, and present the aspect of a luminous cloud.

Throughout the winter did the noble constructor of an unrivalled telescope seize every favourable opportunity to ascertain, if possible, the constitution of the nebula. He plainly saw that all about the trapezium was a mass of stars, the remainder of the nebula also abounding with stars; consequently that such appearances might be regarded as stellar groups, infinitely remote, and yet so vast as to be discernible across those spaces in the heavens of which the magnitude is overpowering to the mind.

SPIRAL NEBULA.

This extraordinary nebula is justly considered as one of the most wondrous objects in the starry heavens. It was discovered by Lord Rosse, and is termed *Lord Rosse's Whirlpool, or Spiral Nebula.*

When examined through an eighteen-inch reflector, a bright and globulous nebula becomes apparent, surrounded by a ring at some considerable distance, of unequal lustre, and subdivided through about two-fifths of its circumference into separate laminæ, one of which appears as if turned upwards out of the plane of the other. When regarded through the six-feet reflector of Lord Rosse's, the interior, or the seeming upturned portion of the ring, assumes the character of a nebulous coil, tending in a spiral form towards the centre: a similar tendency in the streaks of nebula connecting the ring and central mass is further developed, and forms a striking feature. A narrow curved band of nebulous light also beautifully connects the encircling nebula with the ring, and the whole, though not obviously formed of innumerable stars, yet doubtless owes its origin to them.

The position of this *Spiral Nebula* is near the ear of the Northern Greyhound, below *eta* of the Great Bear. Its singular form indicates the action of some powerful and controlling law; it resembles a scroll gradually unfolding, "or the evolution of a gigantic shell."

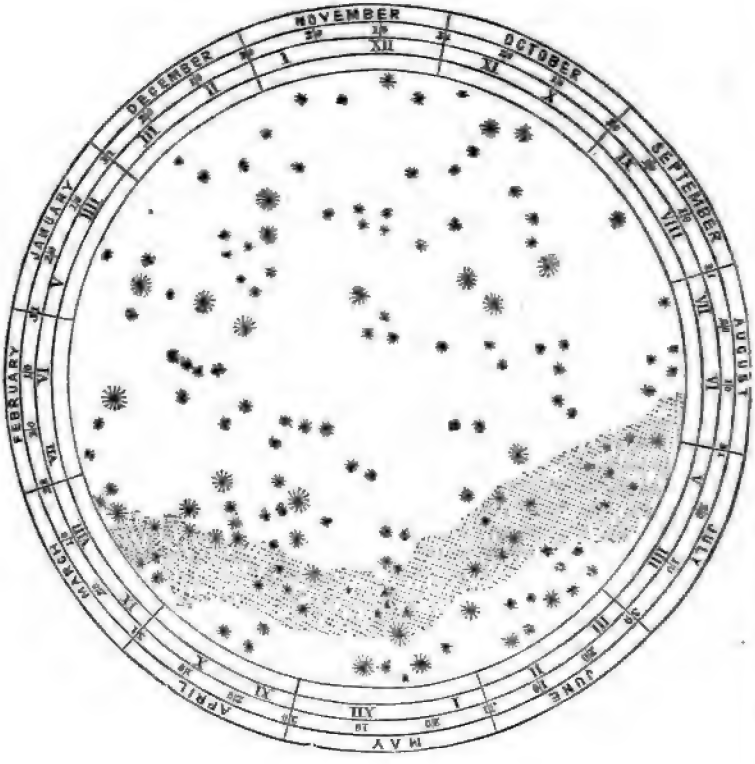
CHAPTER VII.

JULY.

"With hieroglyphics older than the Nile
The heavens are studded. Those who read aright,
Will learn from them thoughts that may grief beguile,
Inscribed in characters of living light."

Such of the northern constellations as were resplendent in the heavens during winter now occupy very different positions. Most of the southern have disappeared, and even those which seem to traverse the immensity of space are scarcely discernible, however brilliant, in the light nights of the present month.

Their positions, however, are as follow:—Westward of the meridian shine the Northern Crown, Libra, and the Serpent. At a considerable elevation, and some distance from the meridian, Arcturus may be dimly



SOUTH CIRCUMPOLAR POLE.

discerned. Far below this beautiful constellation beams the Spica Virginis, very near the S.W. by W. point of the horizon. Cor Caroli may be seen north by west of Arcturus, occupying a high and distant position : immediately beneath, and nearly due west, is Denebola. Westward of the meridian the Great Bear holds an exalted station, his two pointers directed eastward to the Pole star. Castor and Pollux have recently descended below the horizon, towards the north-west ; and Capella, a star which never sets in this latitude, is very near the north point, a few degrees above the horizon. Cassiopeia lifts up her head in the north-eastern quarter of the heavens ; *α* Lyræ looks down from a great height. Eastward of the meridian, and in the same direction, though at a lower altitude, is Denebe, one of the principal stars in the Swan. The Square of Pegasus, formed of four stars, may be faintly discovered, a little northward of the east point, nearly opposite to the place they held in January. Antares, a star of the first magnitude in

Scorpio, has passed the meridian, at an altitude of about 11°. Ras Algethi and Alhague are nearly on the meridian.

Look towards the south-east, for there the bright star Altair, pre-eminent in the constellation Aquila, or the Eagle, is now visible, nearly between two stars of the third magnitude, bearing S.E. and N.W. North-east of Aquila is the Dolphin, at 13° or 14°—a beautiful little cluster of about eighteen stars, including five of the third magnitude, and so arranged as to represent the figure of a diamond, pointing N.E. and S.W. The strange appellation of Job's Coffin has been applied to this pleasing constellation. Sagitta and Vulpecula et Anser, or the Fox and Goose, may be observed north and north-west of the Dolphin. Southward of Aquila is Capricornus; and to the south-east Aquarius, though scarcely distinguishable. The Milky Way, which

> "Nightly as a circling zone thou seest
> Powder'd with stars,"

winds with considerable clearness in the vicinity of Aquila, Vulpecula, Delphinus, and Cygnus.

Those who are abroad in the light nights of this pleasant month may, perhaps, discover the constellations of which we speak.

With the exception of Castor and Pollux, Capella, Lyra, and Cor Caroli, there is little either of poetry or history connected with them. We shall, therefore, introduce our readers to the southern constellations, and reserve the further mention of these to a later period.

The magnificent zones of the southern celestial hemisphere, between fifty and eighty degrees, are especially rich in nebulous stars, as well as in unresolvable nebulæ; and with regard to the starless and desert Southern Pole, the two Magellanic clouds which revolve around it present objects of engrossing interest. The larger, called Nebuleca Major, when examined by the aid of a powerful telescope, presents a collection of innumerable stars, or rather, of irregularly-formed clusters, with nebulæ of various magnitudes, among which occur large nebulous spaces, not resolvable into stars, but rather appearing as luminous clouds in the field of view, athwart which many objects of remarkable and mysterious character are scattered. The Nebuleca Minor is less striking.

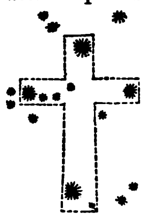
Humboldt spoke with enthusiasm of the delight which he felt in contemplating those two solitary and peerless clouds. "Their appearance," said he, "with the brilliant constellations of the Ship, the gentle sweep of the Milky Way between the Scorpion, the Centaur, and the Southern Cross—in short, the graceful and picturesque effect of the sidereal heavens, seen from the plains of Cumana, have left on my mind an ineffaceable impression."

Such were the reflections of this distinguished traveller, to whom, whatever was new, or beautiful, or wonderful on earth, or in the heavens, opened fresh sources of enjoyment; nought of melancholy was associated with them, but feelings rather of hilarity and proud anticipation. He looked forward to the delight of making his countrymen acquainted with new discoveries, or observations pertaining to the stars; of bringing for their inspection the animal or vegetable productions of another hemisphere. Widely different are the feelings of him who is assigned to far-off regions for

a period of uncertain duration, and who, when contemplating the starry heavens, sees among them no one star that has been familiar in childhood, that has looked through uncurtained windows upon his small couch, where he heard his mother's affectionate good night, and received her blessing.

There is, however, according to the testimony of Humboldt, a mountainous portion of our globe, where the traveller or sojourner is permitted to contemplate all the families of plants, and all the stars of the firmament. In the Andes of Cundinamarca, of Quito, and of Peru, he beholds at a single glance, by day, tropical forms of vegetation, and such as pertain to European homes; at night he sees displayed the constellations of the Southern Cross, the Magellanic clouds, and guiding stars of the Northern Bear, that circle round the Arctic Pole.

Forty-five degrees from the Pole comprise the above starry range, and a portion of the Milky Way, which traverses the southern hemisphere with peculiar brilliancy. The Southern Cross consists of five stars—one of the first, two of the second, and one of the fourth magnitude. Four of these form the Cross, the northernmost and southernmost of which are uniformly in a line with the South Pole, and consequently serve to direct the traveller or voyager in southern latitudes, when traversing the vast plains of the New World, or navigating its seas and rivers. They have nearly the same right ascension, and the Cross is therefore almost perpendicular at the moment when it passes the meridian—a fact well known to every nation beyond the tropics, or in the southern hemisphere. This magnificent time-piece advances very regularly nearly four minutes daily, and hence it is well known at what hour of the night it is either inclined or erect. "How often," wrote a modern traveller, "have we heard our guides exclaim in the savannahs of Venezuela, or in the deserts extending from Lima to Truxillo, 'Midnight is past—the Cross begins to bend!' How often, too, did those words remind us of that affecting scene where Paul and Virginia, seated near the source of the river Lotaniers, conversed together for the last time, and when the old man, at the sight of the Southern Cross, warns them that it is time to separate!" Humboldt speaks also with his usual enthusiasm of the exalted feelings that filled his mind on the nights of the 4th and 5th of July, when in the sixteenth degree of latitude he saw distinctly, for the first time, the Cross of the South. It was strongly inclined, and appeared from time to time between the clouds, where summer lightnings, seeming to flash in and out with almost ceaseless activity, produced a unique and most beautiful effect.



CROSS OF THE SOUTH.

"Oh! 'mid the stars that nightly gem the sky,
Which men have named—their heavenly names unknown,
One starry group doth meet th' inquiring eye
Of him whose steps lead through that stranger zone,
Where palms and citrons cast a grateful shade,
Or far and wide extend the prairies green,
Where neither dale nor hill, nor bower nor glade,
O'er all the vast expanse of grass is seen;
Nor streams are heard, nor of glad birds the song,
But sound of winds that sweep the trackless wastes among.

"That glorious Cross, as if by angels' hands
  Upheld in mid air, nightly meets the eye,
With chasten'd beauty beaming o'er all lands,
  That wide between the line and tropics lie;
The Indian sees it, as he journeys o'er
  The peopled realms his fathers called their own.
The Inca saw it on his palm-clad shore,
  The conquering Spaniard in his blood-bought home.
From age to age, o'er men of every clime,
Hath gleam'd that radiant Cross throughout all time."

This beauteous constellation is represented, in the above engraving, near the meridional lines which point opposite to the month of the May. With the exception of the lowermost star, it appears within the limits of the Milky Way. The stars immediately below the Cross pertain to the Centaur; those on the left, opposite to flowery April, with its buds and migratory birds, belong to *Robus Caroli*, or King Charles's Oak, thus named by some astronomer who pleased himself by associating historic recollections with stars of the southern hemisphere. This constellation contains a star of the first magnitude. *Argo Navis*, or the Ship, is nearly opposite March. Still farther to the left, February claims the Flying Fish, or *Pisces Volans*, which also reveals a star of the first magnitude, named *Canopus:* this star is marked near the left side of the map, about the middle of the month. On the right hand of the Southern Cross may be seen two stars of the first magnitude, *Agena* and *Bungula*, the first being nearest to the Cross. These stars form the two forelegs of the Centaur; they are in the Milky Way, nearly facing the month of June. Opposite the space between July and August, and on the right hand of the Cross and Centaur, are *Circinus*, or the Compasses; the Southern Triangle also containing three stars of the second magnitude in the form of a triangle; and *Ara*, or the Altar.

Look now to the upper portion of the map. The constellation *Equuleus Pictoria*, or the Painter's Easel, consisting of numerous small stars, occupies the left. Next to this, though somewhat higher, is *Dorado*, or the Sword Fish, which contains two or three stars of the second and third magnitudes. *Hydrus*, or the Water Snake, shines to the right of Dorado: above this is *Achernar*, a beautiful star pertaining to *Eridanus*, and opposite the 1st of December. *Toucana*, or the American Goose, occupies a position to the right of *Achernar;* and higher up is the Phœnix, facing November. The Crane is obvious on the right of Phœnix, having two stars of the second magnitude; below which, and beautiful in its locality, is *Pavo*, or the Peacock, with stars of the second and third magnitudes. Opposite the month of August, and below the Peacock, is *Telescopium*, or the Telescope.

DENEBOLA.

REGULUS.

An observatory, supported by public expense, has been erected at Paramatta, in New South Wales, in order to ascertain such stars as are concealed from view by southern declination; in reference to which Sir James Herschel mentioned in an assembly,

who met to do him honour upon his return from thence, that he believed there was scarcely any portion of the southern sky which he had not examined with nearly microscopic accuracy.

The beautiful constellation *Leo*, or the Lion, into which the sun enters during the present month, is now, as it ever was, a symbol of July. The Greek poets rendered it commemorative of the Nemæan lion, a furious wild beast that infested an extensive wood near the town of Nemæa, in Argolis. This animal kept the inhabitants in continual apprehension, till Hercules, the celebrated Theban hero, hearing of their distress, went forth to combat with the lion, which he slew; yet not with arrows, for they could not pierce his skin, but with strength of arm. Hercules boldly followed the enraged beast to his den, and after a close and desperate encounter, succeeded in strangling him, after which he carried the huge creature on his shoulders to Mycenæ, a town of Argolis, and ever after wore the skin as his proudest trophy.

"Two splendid stars of highest dignity"

are conspicuous in the beautiful constellation that bears the name of Leo. The one called *Regulus* is a star of the first magnitude; the other, *Denebola*, pertains to the second. The group may be readily distinguished by their vicinity to the Great Bear; they are chiefly situated north of the ecliptic, passing over countries in the torrid zone where the lion ranges unchecked.

We have already observed that the long, light nights of July are unfavourable for astronomic observations. The moon, however, rides in her beauty through the still calm air, and will shortly become an exclusive object of inquiry and interest.

LUNA—THE MOON.

Peerless orb! poets and moralists in all ages have sung concerning thee, but none more ably or more beautifully than the author of Ecclesiasticus.

"Great is the Most High," he sang, "who made the moon to serve in her season, for a declaration of times, and a sign to the world: the beauty of heaven, the glory of the stars, an ornament giving light in the highest places of the earth."

And what more lovely than a moonlit landscape, when the dew silently descends, and the valleys are filled with light, silvery, wreathing mists; when not a sound is heard except the rush of a far-off torrent, and the sweet melodious descant of a solitary nightingale, warbling where all else is still? There is nought of sadness in such a scene, nor yet of loneliness, but rather the awaking of solemn thought, and the uplifting of the heart above earth's holiest contemplations; yea, even above the glorious moon herself, and the deep, calm, pure, and trackless ether in which she moves, where dwell the stars, and thunders make their path, to that unseen world, wherein archangels veil their faces before the throne of the Eternal!

CHAPTER VIII.

AUGUST.

"The moon,
Full-orb'd, and breaking through the scatter'd clouds,
Shows her broad visage in the crimson'd east;
Turn'd to the sun direct her spotted disc,
Where mountains rise, umbrageous vales descend,
And caverns deep (as optic tubes describe)—
A smaller Earth—gives us his blaze again,
Void of its flame, and sheds a softer day.
Now through the passing cloud she seems to stoop—
Now up the pure cerulean rides sublime."—THOMSON.

THE moon shines with a reflected light derived from the sun, as first conjectured by Thales, the astronomer of Greece, and now clearly ascertained. The light, however welcome, and suggestive of poetic thoughts, shedding a mild radiance over the landscape, and causing all trees and hills to cast deep shadows, is yet devoid of heat. This fact is readily ascertained by concentrating the rays of the full moon, when on the meridian, by means of a powerful burning-glass, and placing in their focus a small thermometer.

Astronomers relate that the inclination of the moon's axis to the plane of the ecliptic is merely about $1\frac{1}{2}^{\circ}$; her seasons, therefore, are unvaried—neither spring nor summer, autumn nor winter, succeeds one the other, and sheds fertility as it passes. Beings constituted like ourselves could not dwell on the moon's surface; she is presumed not to have an atmosphere, as is proved by the fact that no change takes place in the appearance of a star or planet when about to be hidden from view, or occulted—that is, passed over by the moon.

And as regards the general aspect of this world's attendant, those who look at the moon when full must observe that her surface is considerably varied. Seen through a powerful telescope, she appears interspersed with dark spots, ridges, and deep hollows, as represented in the figure at p. 431. The deep hollows are conjectured to be of terrific depth, and are uniformly surrounded by nearly circular hollows, which have no parallel on our globe; they are in number about eighty-nine, and have names given them, commemorative either of remarkable places, or of distinguished individuals. Some astronomers conjecture that the hollows of which we speak are full of water, and that the darkness of their aspect is occasioned by the absorption of the solar rays, while the land reflects them; thus causing that singular diversity on the moon's disc which is apparent to the unassisted eye. Others maintain that there cannot be any water in the moon; a fact, they say, which is obvious from the uniformly serene appearance of this planet—unvexed by fogs or vapours; while the dark portions may be readily accounted for by vast hollows, supposed to be at least three miles deep. Mountains doubtless exist of commanding height, and singularly varied; their lofty summits often reflect the sunbeams, as seen through telescopes. Two or three of the most considerable were observed by Dr. Herschel to be of a volcanic character.

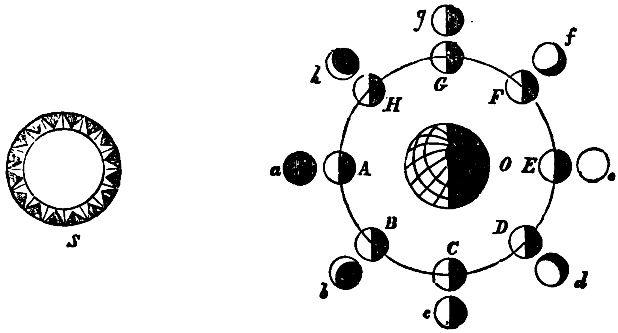
Such, then, is the geographic character of that planet which shines so beau-

teously on a sleeping world—her crescent form at one time gliding amid the clouds, sometimes visible, then again lost to sight, at another shining in full splendour, and causing even stars of the first magnitude to be scarcely visible. She revolves in her orbit round the earth at the same time that we are progressing about the sun; and the consequence of this is, that the moon traces a kind of curling line, because, by the time that her revolution is completed, our rolling ball has performed nearly one-twelfth part of her annual circuit round the great source of light and heat. The moon fulfils her journey in about 27⅓ days, but the time from one full moon to another is about 29½ days: the first is called *periodical*, embracing the period of her course around the earth; the second *synodical*, or the month as agreed upon in the infancy of astronomy, and determined by the coming together of the sun and moon. The difference which exists between the first and latter periods may be readily understood, and is thus explained:—"Although the moon might actually pass round the earth in 27⅓days if the earth were still, yet a longer time is consumed from one phase of the moon to the same phase again, owing to the motion of the earth in her orbit, in the same direction as the moon's motion from west to east. It therefore follows that the extra 2¼ days are spent by the moon in fetching up the overplus of the progress made in the mean time by the earth."

We have stated that the probable want of water, and the extreme rarity or non-existence of a lunar atmosphere, would render the moon uninhabitable to beings constituted like ourselves. Vegetables require the ministration of rain and dews, but neither are compatible with a world destitute of clouds and wells of water; and without trees and shrubs, esculents and herbage, man could not exist. Another barrier consists in the well-known fact that this vast and desolate, yet beauteous planet, though revolving on an axis, performs this revolution in the same time as she takes to accomplish her journey round the earth. Consequently the earth has uniformly the same side of the moon presented to her, and dwellers on that portion of her surface, if such there were, would nightly contemplate the earth, while those who were consigned to the opposite side must dwell in dim obscurity, perhaps even total darkness, unless illumined by volcanic eruptions. Magnificent indeed and glorious would be the appearance of the earth when reflecting the rays of the sun; her disc, having a diameter nearly four times larger than the moon's, would appear of surpassing magnitude, far exceeding that of our lunar attendant, yet rising and setting in like manner, and going through her various phases of light; revolving, too, on her axis nearly thirty times, while the moon is making her usual revolution with a rapidity that might seem almost incredible.

One long day and night, therefore, of equal length, pertain to the moon, while completing her circling course around our planet, and consequently each one must comprise 14¾ of our days. A full glare of light, and almost intolerable heat, must, as before mentioned, be experienced throughout that vast expanse which beams so beauteously in our heavens, while the contrary side, which no one has yet beheld, is enveloped in almost profound darkness and intense cold.

The phenomenon of the harvest moon has often attracted grateful notice, even from the earliest period of the world's history; for who can look unmoved upon that gracious provision which enables the husbandman to avail *himself* of her friendly beams in the time of harvest?



We remember travelling some years since over Sedgemoor beneath the)eams of a fine September moon, when not a sound was heard except the ;entle rustling of the standing corn as the night breeze passed over it, and he sweep of the rapid sickle. Reapers were busily at work, their wives and hildren bound up the prostrate ears, and their long shadows were clearly een upon the stubble; it was nearly as light as day, but in the distance ilvery and wreathy mists gave to the plain itself a singularly illusive ppearance of interminable vastness and extent. We thought of the ontrast which that lovely scene presented, in its soothing sounds and rural ccupations, to the fearful tragedy that was acted in the time of ill-fated Ionmouth, when foe met foe in mortal combat, and the wide moor resounded vith shouts and lamentations. We remembered, also, the beautiful henomenon which enabled the reapers to pursue their pleasant labours to uch an unwonted hour, and in the same manner as the cause and the effect vere explained to us shall we present them to our readers.

"It has pleased the Most High," said our instructor, "to ordain physical auses for the moral government of our world. In the month, therefore, of eptember, when the sun is in the constellation Virgo, and the moon in 'isces, the latter rises full every evening soon after sunset, with very little ifference of time. The same occurs in October, when the sun occupies ibra, and the moon Aries. The former is called the harvest, the latter the unter's moon."

A similar peculiarity with regard to the rising of the moon, with little ifference of time for several days together, occurs in other months. But as t one season the moon is new, at another in her quarters, the fact is scarcely bvious; but whenever occurring, it is caused by the smallness of the angle iade in each month by the ecliptic and horizon, and may be readily exemlified with a celestial globe.

Another beneficent and beautiful provision is afforded by that adjustment f the courses of the sun and moon which assigns the greatest proportion of ioonlight to those countries and seasons of the year wherein it is most ssential. Hence the greater altitude and larger diurnal arc of the moon in inter than in summer.

Other phenomena, ministering to the well-being of mankind, are dependent 1 the relative positions of the earth conjointly with the sun, and are de-

serving of especial notice. These are the Phases of the Moon, Eclipses of the Moon, and Tides.

I.—Phases of the Moon.

Phases is a word derived from the Greek, and signifies appearances: it implies that variation in the illumined hemisphere of the moon, which becomes visible from the earth, occasioned by the moon's change of place relatively to the sun and earth. Revolving opaque bodies, such as planets, necessarily exhibit phases similar to those of the moon, an observation which especially applies to Mercury, Venus, and Mars, of which the orbits are within or next to that of the earth. The more distant planets always present a full face, owing to the great scope of their annual movements.

With reference to the moon, let us imagine that *S* represents the sun, *O* the earth, and *A B C D E F G H* the moon at different parts of her orbit; that the moon is at *A*, a position which causes her luminous half to be turned from the earth. She is consequently invisible to us, a fact represented by the dark globular body, *a*; at which time she is said to be *new*, or in conjunction.

Let us wait three days and a half: the moon will then have moved to *B*, which is termed the first *octant*, or the first eighth part of her orbit. The light side is, as before, towards the sun, but the dark side is not directly towards the earth, whose inhabitants see the moon at some distance eastward of the sun, and catch a glimpse of the illuminated portion; this portion is crescent-shaped; it is figured by *b*, and its points are called *horns*, or *cusps*, the latter word being derived from the Latin *cuspis*, a point.

The moon next travels on to *C*, when she is said to be *in quadrature;* that is, she has performed a quarter of her revolution. One-half of her illuminated surface is now visible, as at *c*: this occurs in about a week after her conjunction. Still journeying in her orbit, she arrives at *D*, where nearly the whole of her illuminated surface is visible to the earth at *O*: this is her second *octant*, and she presents an appearance such as *d*, in which about three-fourths of her illuminated surface is visible. This is the *gibbous* phase, a word derived from the Hebrew, implying *prominence* or *convexity*.

Three more days and a half must be waited for, and then the moon, occupying her place at *E* on the further side from the sun, is gloriously shone upon, and becomes a full moon, visible to the earth at *O*, and presenting the appearance of a luminous circle, as *e*.

Shortly after the moon begins to wane. When arrived at *F*, she appears to a spectator very much the same as when seen at *D*, but the flattened or imperfect edge is turned somewhat round or away from the sun; *f* represents her appearance to the eye, and this is her third *octant*.

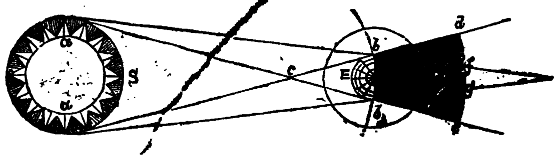
The last quarter is represented at *G*, where the moon bears a general resemblance to her position *c*, when seen in her first quarter, and is represented at *g*. The point *H* is the last *octant*, when this wandering planet has performed seven-eighths of her usual round, and presents the form of a crescent, as at *h*, pale and faint, yet beauteous and ever welcome, though rather when progressing towards than receding from the view.

Proceeding in her orbit to the point *A*, she again becomes invisible, and is represented by the dark circle *a*, bearing the name of New Moon, and being in conjunction.

All these dissimilar phases or appearances of the moon necessarily result from her being an opaque body, reflecting the sun's light, and revolving round the earth from one new moon to another.

II.—ECLIPSES.

The wonderful phenomena of eclipses have often been resorted to by designing men in order to impose upon mankind, or to preserve themselves from impending evils. Columbus practised a deception of the kind when driven by great necessity, and the prospect of utter destruction to himself and his companions. He had been wrecked on the island of Sumatra, his stock of provisions was nearly consumed, and the natives refused to assist him. In this emergency he remembered that an eclipse of the moon was about to take place, and having obtained a hearing from the native chiefs, he told them that a signal judgment was about to fall upon them, in consequence of their heartless refusal to assist their suffering fellow-creatures; in token whereof the moon, then riding in majesty through the heavens, would be deprived of her light. On hearing this some of the audience began to laugh, and treated the announcement with contempt; others became alarmed; and even those who derided Columbus were observed to cast many an anxious look towards the heavens. Imagine, therefore, their terror and amazement when the clear full moon gradually became darkened, till at length she was scarcely visible. Most earnestly then did the chiefs implore that the dread sign of impending judgment might be withdrawn, while they sent provisions in all haste to the suffering Spaniards; and Columbus,



A LUNAR ECLIPSE.

availing himself of the favourable moment, assured the chiefs that they need not fear, for that in a brief space the moon would again be visible. Shortly afterwards she emerged in full splendour from her temporary obscurity, and the Indians, believing that Columbus was endowed with supernatural powers, never again refused any assistance that he required.

Both in China, Hindostan, and Chaldea, attention was directed by the earliest astronomers to the interesting subject of eclipses: it is believed that their occurrence was predicted with considerable accuracy, but this is foreign to our present subject. We shall, however, show by what means that obscuration of light is caused which obtains for this celestial phenomenon the name of *eclipse*.

Here the question naturally arises—Why does not an eclipse take place at *every* new and full moon? Simply because the moon's orbit is inclined to that of the earth; or, in other words, "because the moon, in moving round the earth, does not keep in the same plane as that in which the earth revolves about the sun. The two planes are inclined to each other at an angle of about $5\frac{1}{4}°$; so that in one part of her orbit the moon is above the plane of

the earth's orbit, and in another part she is below it." It is consequently obvious that only at the time when this fair planet is in either of her nodes is she in the plane of the earth's orbit.

Hence it follows that an eclipse must be restricted to that period when the moon is *at* or *near* one of her nodes; that, further, if she be far removed from her nodes at new or full moon, she is altogether above or below the line which joins the earth and sun; but that if she be exactly at the node, there will be a *central eclipse;* and if within certain limits on either side of one of her nodes, a *partial eclipse.*

A Lunar Eclipse is owing to the opaque body of the earth hindering the sun's rays from reaching the moon.

In the preceding figure *S* represents the sun, *E* the earth, *m* the moon in conjunction. The sun shining upon the earth causes a shadow to be thrown behind, tapering to a point like a sugar-loaf, which cone-like form results from the sun being much larger than the earth: if the moon was beyond the shadow of the earth, she would of course remain unobscured; but as a portion of her orbit is within its reach, she is necessarily subjected to its influence.

When an eclipse of the moon is about to happen you will observe that her disc, or surface, appears as if covered with a mist: this arises from her having to pass through the earth's partial shadow, or *penumbra,* before reaching her real shadow.

In order to understand this slight diminution of the moon's brightness, observe that rays of light from the two extreme edges of the sun, *a a,* pass by the edges of the earth *b b,* and go on in the direction *b d* and *b e,* having previously crossed at *c*; observe, further, that the upper part of the penumbra, *d b f,* receives light from the upper part of the sun, although the earth prevents it from receiving light from the lower part; moreover, that the lower part, *g b e,* of the penumbra receives light from the lower part of the sun, although the up rays are intercepted by the earth. The real shadow is, therefore, surrounded by a partial shadow, which imparts to the moon that singular duskiness, which increases as she draws nearer to the real shadow, and receives still fewer rays from the source of light.

VIRGO.

A lunar eclipse uniformly commences on the eastern edge of the moon, and may be seen by dwellers on half of the earth's surface; it cannot last longer than $5\frac{1}{2}$ hours from the moment of her entering the earth's partial shadow to quitting it; the moon cannot be eclipsed partially and totally more than $3\frac{3}{4}$ hours, and as respects the latter, it never continues more than $1\frac{3}{4}$.

The beauteous constellation Virgo is now conspicuous in the heavens, bounded on the north by Boötes and Coma Berenices—on the east by Libra—*on the south* by Crater, Hydra, and Corvis—and on the west by Leo. The

most brilliant star in Virgo is *Spica Azimech*, or *S. Virginis*, near the ecliptic—last of the summer signs, the sixth in order, and the harbinger of coming harvest. This group of stars bore in ancient Egypt the name of Iris —among the Greeks that of Ceres, the goddess of corn.

Poets tell that though other names have been assigned her, Virgo was, in truth, Astræa, daughter of Astræus and Aurora, and the goddess of justice; that she dwelt on earth during the golden age; but that, when men ceased to love and obey her laws, she ascended to heaven, whither every benignant divinity or genii had preceded her. Were it possible to remove the mists of ages which brood deeply over this honoured name, we should undoubtedly discover that Astræa was some benefactress of mankind.

CHAPTER IX.

SEPTEMBER.

> "There is society, where none intrudes,
> By the deep sea, and music in its roar."

HEAR ye not the solemn rushing of the waves; and see ye not how gradually the sunken rocks and sea-weeds, beauteous deposits of the ocean, the wide shingly space, and belt of fine sand, are being submerged in all directions? Well for us that we left yonder cave before the tide began to rise, or else we should have had to wade, knee deep, through the dancing spray. A brief space only has elapsed since we collected corallines and sea-anemones in rock basins filled with clear, transparent water. Now the huge stones, by which they were encircled, are lost to sight; their presence is alone discovered by the eddying and whirling of the restless waves immediately above them; and now a might of waters rushes impetuously upon the beach.

But why is this? Last evening we walked securely where now no human foot may venture. That beautiful rock basin—that little watery world—beside which we sat unwearied, gazing on the wonders which it contained; our pleasant walks upon the firm sand, and among sunken rocks of all forms and hues, are covered with restless waves. Know you the reason of such a change, and why old Ocean has advanced towards the shore with such resistless force? Ask yonder fisherman, who is preparing to cast his net into the sea. He would laugh, perhaps, at your simplicity, and tell you that it is the time of high tide. You seem inclined to laugh also, wondering why any one should ask a question which the youngest child upon the coast may answer. "The tide," say they, both youths and aged men, "is coming in." And yet what definite idea does that short sentence convey to the inquiring mind as regards the reason for such a change? None whatever. In the fisherman it awakens thoughts connected with his craft; in the sailor, remembrances of far-off shores; to many who daily observe its progress and receding, pleasant anticipations of shells and sea-weed; whilst others idly gaze upon the tide as a thing of course, unvarying in its movements, like the rising and setting sun.

And yet the "world's great pulse" is worthy of deep thought; and let us

not rest contented with knowing that what has been must be. These beetling rocks afford a cool retreat and resting-place; and much that we have learned on the subject can be more readily imparted when the suggestive object is in view.

We know that one of the properties of matter is to attract other matter towards itself, however distant; that a small loadstone will take up a little key, while a larger magnet acts with greater force. We cannot conjecture what attraction really is, but its effects are obvious. Every one has heard the story of Sir Isaac Newton, in whom the falling of an apple from a tree excited a train of thought which laid the foundation of all correct knowledge concerning the movements of heavenly bodies. Men, in after times, rendered familiar those deep reasonings and calculations, which otherwise we could not understand; and such are the results of much combined information on the subject.

Bear in mind that the force of attraction is subject to variations, with respect to distance between attracting and attracted masses. Thus, if a mass of iron be the attracting body, acting upon another mass with such power as to make it move through twenty feet in a second of time, supposing the larger mass to be removed double its former distance, then the attraction will become necessarily so much weakened, that the lesser mass will move only five feet in a second, or with one-fourth of its former rapidity.

Results of a gigantic kind are produced by these simple principles, when applied to those immense bodies which men call planets. But our business is not now with these; only as attraction has reference to all matter, and the earth and moon reciprocally attract one the other, the knowledge of this fact will help us to understand that though the moon's attraction is not felt to influence the solid matter of the earth, it may produce a visible effect on the liquid weight of half the globe. Exactly in this way:—Suppose an attractive power—that of the magnet, for instance—be applied to a compact piece of iron, the iron springs forward to meet it in a solid form, merely because the composing particles are closely bound together. Suppose, further, that you move your hand rapidly in a basin of water, the water will be urged over the edge of the basin; yet, when the hand is removed, the liquid element settles again, smooth and unaltered, as before; or if a stone be put into it, no ruggedness or inequality is perceptible; the waters close round it, filling even the smallest interstice, and showing the ease with which their particles may be separated, without producing any obvious effect. Nothing of the kind occurs with regard to solid masses; and from this difference results that wonderful effect which we have just witnessed in the rushing onward of the tide.

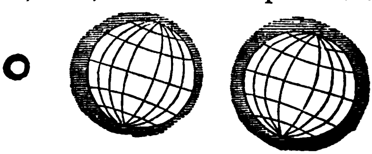


Fig. 1.

As the earth and moon mutually attract each other, their distance is regulated by this simple fact, as also by the velocity with which the moon progresses in her circling dance. There is, consequently, no perceptible difference from year to year as regards the solid earth; but as respects the sea it is otherwise: the moon's attraction of the earth is neutralized *by the counteracting attraction of the earth for the moon, but the*

waters, which cover three-fourths of her surface, are perceptibly drawn towards that quarter where the moon exercises her influence.

All this is obvious; but how wonderful is the fact that not only is the water nearest to the moon drawn towards her, but that the water on the opposite side, and consequently far removed from her influence, is affected in like manner. The real form of the sea, therefore, when thus acted upon, may be compared to that of an egg, the small ends being formed by the attraction of our sister planet, and the flattened sides from the diminution of water in those parts, as shown in the above figures. Hence the same effects are produced *twice* in the lunar month, at *new* and *full moon*, when the waters are attracted towards her, either near or more remotely—that is, at the *zenith* and *nadir*.

The sun also exercises a certain influence, yet not so powerful as that of the mild luminary which reflects his beams. Although considerably larger, his distance is in a much greater ratio, and therefore his specific attraction is far less, being considered as 1 to 5. We must, consequently, subtract the sun's attraction, according as it assists or opposes that of the moon.

We will suppose that the moon is in *quadrature*—that is, in the first or last quarter; the Sun, the Earth, and Moon (S.E.M.) forming a right-angled triangle. Thus circumstanced, the sun acts on a portion of the earth at *b*, which is precisely a quarter of a circle removed from the spot *a*, on which the moon acts, and which is depressed in consequence of that action. Thus it happens that the moon occasions the waters to rise at the two parts *a* and *a'* in the proportion of 5, while the sun's influence at *b* and *b'* is in the proportion of 1; and by these means four risings of the water are occasioned instead of two. By subtracting, therefore, the sun's effect 1, from the moon's effect 5, four remain, and this expresses the highest tide occasioned by the position of the heavenly luminaries.

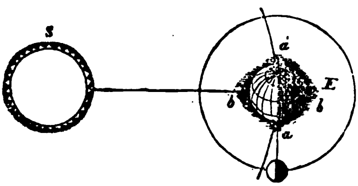


Fig. 2.—NEAP TIDE.

But supposing that the moon is either *full* or *new*, she forms a line with the earth and sun, and the action of the sun and moon being concentrated to the same points, the risings of the tide will be much greater than if the sun was otherwise situated. Whether the moon be new, as at *m*, Fig. 3, or full, as at *m*, Fig 4, it does not signify; in either case the effect is to raise the waters at *a a'*, and to depress them at *b b'*, because the attractive force of the two bodies, when the moon is new, operates most powerfully at *a*, less at *a*,, and partially at *b* and *b'*. When the waters subside at *b* and *b'*, the greater portion flows off towards *a*, and the lesser bears its tributary current to raise the waters at *a'*, where they are less affected by the attracting bodies. The same may be said with reference to the full moon, Fig. 4, where the rise at *a* and *a'* is followed by a subsiding at *b* and *b'*.

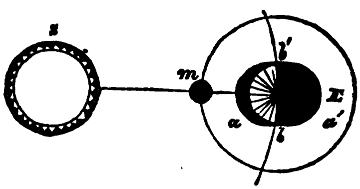


Fig. 3.—SPRING TIDE AT THE NEW MOON.

It must not, however, be forgotten that the singular fact of high water at the zenith and nadir at one and the same time owes much to the centrifugal force of the water; that is, to the effort which a body compelled by gravitation to revolve in a curve, continually makes to fly off in a right line at a tangent to that curve. "This force is caused by the rotation of the earth on its axis, and is greatest at the contrary side of the earth to the moon." High water, therefore, nearest to the moon, results from her positive attraction; on the side furthest from the moon, to uninterrupted centrifugal force.

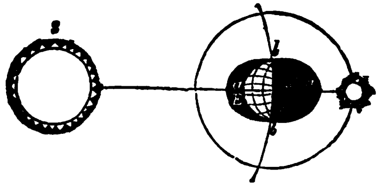


Fig. 4.—SPRING TIDE AT THE FULL MOON.

Such is the theory of the tides. "As the earth," says a modern writer, "revolves on her axis, the protuberant waters travel in the opposite direction, being chiefly influenced by the moon, and, to a certain extent, by the sun. The former comes to the south of us, every day later than on the preceding; and the time of high tide is also later every day in the same proportion, which sufficiently indicates the superior attraction of the moon." We have already noticed that two opposite high tides occur simultaneously on the surface of the earth; and hence it follows that every part experiences two high tides and two low tides intermediate between them during the period of its diurnal revolution. In the open sea these alternations take place at intervals of about six hours apart; but in rivers considerable irregularities occur, owing to impediments occasioned by rocks or natural barriers; and hence the tide rises higher than out at sea. Now, in order to supply the additional quantity of water to those two portions which are in a line with the centres of the moon and earth, both seas and rivers, on either side, contribute a portion of their waters, yet only temporarily; for the waters come back to them again in about six hours, although, as we have just remarked, the ebb and flow are frequently retarded or increased by local circumstances; hence it follows that high tides happen at different times in portions of the world that are nearly contiguous.

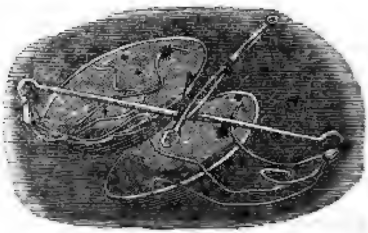
The revolution of the moon around the earth occurs while the earth is making rather more than one revolution on her axis, during which time two ebbs and two flows are completed; high water is consequently about three-quarters of an hour later on each succeeding day. Tides at new and full moon, which are greater than those when the moon is in quadrature, are called *spring* tides, the other *neap* tides. Tides, moreover, vary in their fulness from another cause, namely, as the moon revolves in an elliptical orbit, she is at one time nearer to the earth than at another; and consequently, if the spring tide happens when this is the case, the tides will be higher than if she was more remote; if, also, the earth at the same time be at her nearest distance from the sun at spring tide, the flowing of the waters will then be at the greatest that can occur.

We might naturally conjecture that *high water* would be uniformly, in oceanic or river sites, *immediately beneath* the moon; but such is not the case. The moon's attraction requires time in order to produce a full effect; and sailors find, accordingly, that three hours must elapse, even when out at sea, before the completion of the highest tide; or, in other words, if the

moon looks down on any given spot at twelve o'clock, it will not be high water until three. Hence it happens that the spring tide does not take place till about three days after new or full moon, and that the greatest spring tide happens in February and October.

Should it chance that the moon is above the horizon more than twelve hours in the twenty-four, one of the tides is higher than the other on that day; and this is readily accounted for, because the attraction of the moon acts upon the waters that are immediately beneath her for a longer period. If, on the contrary, this fair planet is above or below the horizon for nearly equal periods, the two tides are also nearly equal.

Libra, or the Balance, is the first of the autumnal signs, and the seventh amongst its brethren. Emblematic of that equality which subsists between the day and night, its denotive character ♎ is aptly represented by a pair of scales *in equilibrio*, because the days and nights are nearly equal, except at the poles. In poetic fiction, the Balance belongs to the goddess Astræa, and is referred to by Homer, Virgil, and Milton.



LIBRA, OR THE BALANCE.

Look up! The heavens are now gloriously bedecked with stars. At first a very few of the largest magnitude became visible; others succeeded when twilight deepened into night; and now we can distinguish clearly such as may well detain us for some time longer beside the deep, deep sea.

Altair is nearly on the meridian at an altitude of 46½°; and *Vega*, or *α* Lyra, is nearly west of the meridian, N. by W. from Altair. Nearly midway between that star and the south-western point of the horizon, *Ras Algethi* and *Ras Alhague* have become visible; the first pertaining to the constellation Hercules, the second to Serpentarius, or the Serpent-Bearer, North-westward of Vega, and at nearly 20° distant, gleams the head of Draco, or the Dragon. Arcturus occupies a position W. by N., within 19° of the horizon. The Northern Crown may be seen at a higher point than Arcturus; it is nearly due west, and somewhat nearer to the horizon than to the zenith. The Great Bear appears in a north-westerly direction, though in a lower altitude than has been hitherto his wont. Cor Caroli, or King Charles's Heart, verges upon N.W. by W., at 23° of altitude. Eastward of the meridian beams Capella, in a direction nearly N.N.E., at an elevation of 15°. *Menkalina*, or *β* Aurigæ, a star of the second magnitude, is seen east of Capella, or the Goat, at a little lower elevation. Midway between the zenith and the north-eastern horizon, Cassiopeia, "the proud Ethiop queen," appears in the north-east. We have not forgotten the Square of Pegasus, though at a greater elevation than in July, and now apparent in a direction E. by S. North-east of Altair, at an altitude of above 50°, the Dolphin has become visible a few degrees eastward of the meridian.

The southern quarter of the heavens is now beautifully varied with numerous constellations, although, with the exception of Aries and Pisces, they are mostly at a low altitude. The first may be readily discovered in the direction E. by N.; the second is due east, and next to Aries. Aquarius has risen westward of Pisces, in a locality S.S.E.; Capricornus westward

from Aquarius, nearly in the south; Sagittarius, or the Archer, and Sobieski's Shield, are also S.W.; while Scorpio is situated still further to the west.

See you not that large irregular whitish zone stretching athwart the sky from one part of the firmament to another? That mighty zone is called the Galaxy, or Milky Way, and when traced throughout its circling path, is found to encompass the heavens, though broader and more brilliant in some portions than in others. Astronomers and poets in all ages have alluded to this mighty zone, but none more beautifully than Milton, in his Seventh Book of *Paradise Lost*, when describing the ascent of angels in the train of their Creator:—

> "So sung
> The glorious train ascending: he through heaven,
> That open'd wide her blazing portals, led
> To God's eternal house direct the way—
> A broad and ample road, whose dust is gold,
> And pavement stars, as stars to thee appear,
> Seen in the galaxy, that milky way,
> Which nightly as a circling zone thou seest
> Powder'd with stars."

We have traced this fair circle in the map of stars on Mercator's projection; let us endeavour to apply the knowledge which we have gained by observing its actual position in the heavens. Commencing from the head of Cepheus, or about 30° from the North Pole, we observe that it proceeds through Cassiopeia, Perseus, Auriga, part of Orion, and the feet of Gemini. At this point it crosses the zodiac, winds across the equinoctial line into the southern hemisphere, and divides the Unicorn and ship Argo, where its luminosity is most conspicuous. Charles's Oak, the feet of the Centaur, the Cross, the Altar, and the tail of Scorpio, the bow of Sagittarius, and a part of Ophiuchus, lie also in its course. When passing over the zodiac into the northern hemisphere it is parted into two branches: of these the first runs through the tail of Scorpio, the bow of Sagittarius, the shield of Sobieski, the feet of Antinous, Aquila, Delphinus, the Swan, and Arrow; the second winds through the upper portion of the tail of Scorpio, the side of Serpentarius, Taurus, Poniatowski, the Goose, and the neck of the Swan, at which point the two branches again unite, and proceed to the head of Cepheus, where we commenced our observations, after remaining separate for more than 100°. We may also observe a brief separation of the Milky Way between Cassiopeia and Perseus, forming two small streams, which again unite in the sword of Perseus.

How beautiful is this wondrous zone, whether appearing dense and luminous, or faint and scattered, whether broad or narrow! In some places its breadth is about four or five degrees, in others from ten to eighteen degrees; and such is its peculiar appearance, that at every season of the year it is more or less visible, though most conspicuous and clear during the months of August, September, October, and November.

Astronomers relate that this "thin gauzy band of light," which seems to encircle the dome of heaven, consists of innumerable stars, and yet so distant as to present only in their aggregate that dim zone which is called the Galaxy, or Milky Way. The elder Herschel, by means of a powerful *telescope*, reckoned, in one portion only, about 250,000 stars.

CHAPTER X.

OCTOBER.

"The sun
Is centre to the world, and other stars
By his attractive virtue and their own
Incited, dance about him various rounds,
Their wandering course now high, now low, then hid,
Progressive, retrograde, or standing still."

"FATHER," said Walter, "why is it that one star twinkles, and that another shines quietly; that some are large, and others small?"

"My child, I cannot tell you," replied the father; "but this I know, that as one star differeth from another star in glory, so is the resurrection of the dead. It is sown a natural body, it is raised a spiritual body; and never do I look up to the stars without thinking of your little sister, at whose burying those comfortable words were spoken by the minister."

"You tell us the names of flowers in the fields, father," answered the eager youth; "I know the harebell and the cowslip, the primrose and marsh-marigold, the cuckoo-flower and corn-cockle, because you taught me;" and thus saying, Walter looked beseechingly in his father's face, begging him to tell something about the stars.

It chanced that an astronomer was passing at the time, on his way to the summit of a neighbouring hill, in order to observe the beauty of those sparkling luminaries—for his own dwelling lay low among the trees. He heard the question of young Walter, and opening the wicket-gate that led into the cottage-garden, he courteously asked leave to enter.

John Rogers, the master of that small domain, was a working man of no ordinary intellect. He taught his children the names and uses of such trees and flowers as best he knew, and concerning the habits and instincts of different animals; it was his greatest delight to gather them around him in the cottage porch, after his day's work; and that evening he was explaining the wonderful construction of the meadow-saffron, when young Walter, thinking that his father knew as much about stars as flowers, wished to learn somewhat concerning the myriads that sparkled above his head.

The astronomer was cordially welcomed, and having seated himself in the rustic porch, he sought to adapt his language to his hearers while he unfolded a small portion of his favourite science. The evening was serenely beautiful; the air fresh, yet mild; the trees displayed those gorgeous tints which adorn the woods in autumn—some were russet, others yellow, others, again, of the brightest orange; and on high, the stars twinkled with that vivid clearness, which often renders our autumnal evenings so eminently beautiful.

"My young friends," said the astronomer, "you are happy in possessing a parent who instructs you concerning the plants and animals, and who enables you to regard them as gifts from your Heavenly Father, to be used for your advantage, and to His glory. He can teach you many things with which I am unacquainted, while I, on my part, have acquired some kinds of knowledge to which his attention has not yet been directed. Shortly, however, he will be able to answer your inquiries respecting yonder stars,

and in the mean time I will endeavour to make you understand wherein a planet differs from a star.

"Stars shine by their own native light, having, so to speak, light within themselves. They glitter in the vast dome above our heads like little spangles; while such of the planets as become visible at different periods, and may be seen with the naked eye, are illumined by the sun, however distant.

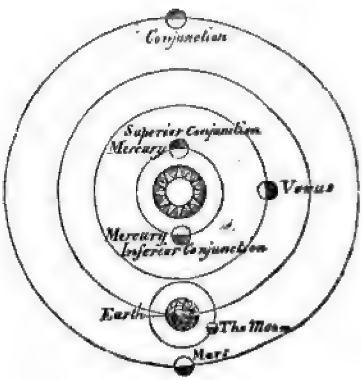
"The word 'planet' signifies a wanderer—it is a heavenly body which moves round another, as the earth on which we dwell revolves about the sun. Several have been discovered; the circles in which they perform their ceaseless journeys are termed orbits; and as two of them are nearer to the sun than we are, they are called inner, or interior; while the others, being more distant, are termed outer, or exterior.

"MERCURY.

"Each planet has a distinctive name. The one nearest to the sun is Mercury; and the time which he takes in going round the sun is nearly eighty-eight days—a period that forms his year. In reference to which, you must bear in mind that spring and summer, autumn and winter, are occasioned by the revolution of the Earth in like manner; as also that day and night are caused by her turning round in twenty-four hours, as you have seen an apple when the string to which it is suspended has been twisted, and the apple set in motion.

"This movement is termed the revoluion of the Earth upon its axis. Mercury, also, has his day and night, which are longer than ours by five minutes and a half.

"The amount of light and heat received by this planet is very considerable. As regards the first, it is stronger than in the longest of our summer days; as respects the latter, it surpasses the hottest of our summer months, and both naturally result from the nearness of Mercury to the sun. Hence we do not often speak of him as either a morning or evening star; nor is he often visible, because he is lost as it were in the brightness of the sun's beams. True it is, that when in windy weather both clouds and vapours are chased away, this planet may be discerned immediately before sunrise in the morning, and just after sunset in the evening. He is visible in the constellation Virgo during the present month, and may be distinguished by his bluish tint. If the weather is favourable, and the sky cloudless, you can discern him as a morning star, rising at 4h. 36m. on the first; at 4h. 25m. on the 27th; at 4h. 56m. on the 18th; and at 6h. 24m. on the last day. He is most favourably situated for observation between the 4th and 12th, rising till the 20th near the east, and on the 25th at the E. by S. *points of* the horizon.



OPPOSITION.

"You will like to know how it can be proved that planets do not shine by virtue of any inherent light, but by such as is reflected from the sun. Simply because when Mercury, for instance, is seen at the greatest distance from the orb of day, his illuminated surface has nearly the form of a half circle—more or less, according to the position of the earth. But when he is passing round the opposite side of our rolling planet, the bright portion becomes more than a half circle—it assumes that form which is called *gibbous;* or, in other words, is greater than half, and less than full. When, therefore, Mercury is at his greatest distance from the Earth, the intermediate sun shuts out all view of his swiftly-moving orb, and, consequently, the whole of that part which is brightly shone upon can never be seen from the Earth. When, on the contrary, he emerges on the other side of the Sun, he again becomes visible, and rapidly takes the form of a semicircle, while journeying to the position in which he forms a triangle with the Sun and Earth. When, also, he approaches nearer to the Earth, his half-circular appearance, or phase, diminishes to a crescent; and this assumes the smallest dimensions when Mercury is exactly above or beneath the Sun, in which position very few of the solar rays are reflected from his surface—and even those few are nearly lost to him who anxiously watches, through his telescope, the 'nimble-footed planet,'

"whose disc
Can scarce be caught by philosophic eye,
Lost in th' near effulgence of the solar blaze."

"Conjunction and opposition are terms that frequently occur, and can best be understood by referring to the aspect of the heavens, as shown on a small chart, which you will soon be able to understand.

"Supposing Mercury to be exactly between the Earth and Sun, he is said to be in inferior conjunction with the Sun; but if that great fountain of light be exactly between this planet and ourselves, he is in a position that is termed superior conjunction; the terms inferior and superior, as before observed, having respect to smaller or greater distances from the Earth. If, moreover, Mercury, or any other planet, be either a little below or above a line that may be drawn from the centre of the Earth to the Sun, it is still said to be in conjunction.

"Astronomers also apply the term *opposition* to two planets when so situated that one particular plane, passing through both their centres, will also pass through the centre of the earth, the earth being between the two bodies. This position cannot occur with respect to Mercury and Venus, because their orbits are smaller than that of the Earth, which can, in consequence, never pass between them and the great centre around which the heavenly luminaries revolve.

"'Plane' signifies in Latin *smooth;* it is an imaginary surface, supposed to pass through the centre of the Earth or other planets, and extending to the heavens, is called the plane of the Earth's orbit.

"VENUS.

'Fairest of stars, lost in the train of night,
If better thou belong not to the dawn,
Sure pledge of day, thou crown'st the smiling morn
With thy bright circlet!'

"Thus sang the poet of Venus; and we need not wonder that men in all

ages have hailed with delight that beauteous planet which glitters like a gem in the immensity of space, when the most conspicuous constellations can hardly be discovered.

"No other planet shines with such clearness and brilliancy; nor is this extraordinary. Venus is our nearest neighbour; she is, moreover, of large dimensions, her diameter being at least 7,800 miles, her orbit about 433,000,000 of miles; and this she traverses in about 225 days: eight of her years are, consequently, about equal to five of ours.

"Look at that lovely planet. We must watch her for a considerable time before any change is perceptible in her position among the stars, and yet she moves in her orbit at the rate of 75,000 miles an hour; and as regards her own daily rotation, it occupies about twenty-three hours and twenty-five minutes, a rotation which may be accurately noted by watching the permanent spots on her surface. Venus, during the present month, is in the constellation Virgo till the 24th; she then passes into Libra, and remains among the widely-scattered stars of that constellation till the end of October. Those who like to note the periods of her rising and setting may observe that they occur near the east and west points of the horizon on the 1st day; at the E. by S. and W. by S. on the 11th; and at the E.S.E. and W.S.W. towards the end of the month.

"It is a beautiful sight, my friend," continued the astronomer, "to see this glorious planet, in the stillness of the silent night, visible above the horizon for more than three hours before a kindling glow announces the break of day, and often for as long a period after the sun has set." The peasant answered "that the same bright star had often cheered many a solitary hour when watching his master's flock on the wide moor; it had seemed to him as a friend, whose familiar countenance was ever near—as one who cared for and watched over him—the first to rise, the last to set."

"Yes, and when you look upon the star again, which men in olden time termed the Light-bearer, because of her long-continued radiance and the beauty of her beams, remember that this star possesses a degree of light and heat nearly twice as great as what is assigned to us, and that, in consequence of her sloping position towards the sun, some portions of her surface may have four seasons twice in the year.

"'The heavens declare the glory of God; and the firmament showeth his handiwork. Day unto day uttereth speech, and night unto night showeth knowledge. There is no speech nor language where their voice is not heard.'* The most unlearned may hear aright concerning the majesty and goodness of their great Creator; but how much is the pleasure heightened, and what thoughts are awakened in the mind, when somewhat is known respecting the laws by which the movements of the stars are regulated, and the wonders that pertain to each!

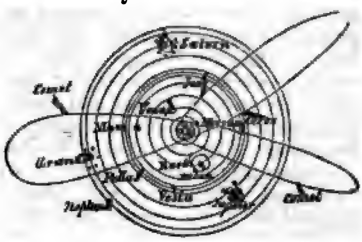
"Let us now consider the outer planets, or those which revolve around the Sun; and in order more fully to comprehend them, I shall supply you with a sketch of the Solar System.

"Mars is the nearest planet exterior to the Earth, and is remarkable for a peculiar ruddiness of colour. Why it has pleased the Creator that a planet which is farther from the Sun than any other should not be provided with a

* Psalm xix. 1—3.

moon, is a question which none have solved. There is, however, good reason to believe that the nature of his atmosphere, or, in other words, the air which surrounds him, is such, that so much of the Sun's light is absorbed and made available as to render a moon unnecessary.

"This planet is rather more than half the size of the Earth. His year consists of about 687 of our days, and he revolves upon his axis in a little more than 24 hours and 39 minutes; hence his day is somewhat longer than ours. The period of his revolution around the Sun is about 668 of his days, and this he accomplishes with a velocity of 53,000 miles an hour. He is conjectured to receive about half the degree of light and heat which is assigned to us, but in a similar proportion throughout the year, in consequence of his axis being inclined to the plane of the ecliptic nearly at an angle with ours, though much further off than the Sun. By means of a good telescope his poles are seen to present a white appearance, which is most observable when they are inclined from the Sun, more faint when turned towards him. Astronomers conjecture that these white spots are polar snows; and this conjecture is confirmed by their partial disappearance and increase in the summer and winter of the planet.



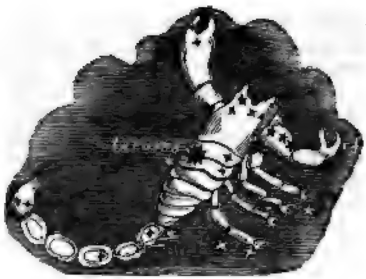
THE SOLAR SYSTEM.

"Another planet, called Jupiter, largest among his brethren, and consequently brightest, with the exception of Venus when she approaches near the Earth, is 89,000 miles in diameter. He moves around the Sun in about twelve years, and revolves upon his axis with a rapidity twenty-five times greater than that of the Earth. His distance from the Sun is very considerable, and therefore the dwellers on his surface receive less light and heat than we enjoy. But this deficiency is made up to them in a great degree by the swiftness of his rotation, and the presence of four attendant moons. Unlike other planets, his axis being perpendicular to the plane of his orbit, his seasons are uniform, and his days and nights of the same length.

"When examined through a telescope, Jupiter appears as if surrounded by numerous belts, that vary considerably; at one time they are reduced to one or two in number; at others they amount to seven or eight; occasionally they continue stationary for some months, and then again they alter in the course of an hour. It has therefore been conjectured that these zones or belts are caused by changes in the atmosphere, and that the darker portions are the body of the planet, seen through a luminous, though cloudy medium.

"Four moons revolve around the planet. If the nights are clear, they may be seen with a telescope that magnifies considerably less than thirty times, and the appearance which they present is beautiful. Varying in the periods of their revolution, the first occupies one day and eighteen hours; the second, three days, thirteen hours; the third, seven days, three hours; the fourth, sixteen days, sixteen hours. These moons resemble our attendant planet, and each revolves on its respective axis around the globe, which

they are evidently designed to enlighten: they were discovered by Galileo —first fruits of the invention of the telescope, that wondrous combination of convex and concave lenses, placed in certain positions with regard to one another, which enabled that illustrious astronomer to explore the starry heavens. The discovery, arising from a trivial circumstance, has been improperly called accidental. But those who read the Holy Scriptures entertain a different opinion. They remember two portions of the inspired volume, where the devising of curious works in gold and silver, and in brass, in cutting stones and setting them, and in all kinds of cunning work, as also the common operations of husbandry, are mentioned as gifts from God. The invention of the telescope may, therefore, be considered as a glorious gift to man, humble as was its origin; for Galileo simply placed two lenses in an organ pipe, which served him for a tube, and thus constructed the first telescope that the world ever saw. On turning it towards the planet Jupiter, he perceived a small star in his vicinity, afterwards three others; subsequently he ascertained that they revolved round the planet, in consequence of their coming in front of his illuminated surface, travelling to one side, then passing round him, and emerging on the other. In this way were the moons of Jupiter discovered, and in after years the entire heavens were explored and accurately mapped; and phenomena were brought to light, concerning whose existence no astronomer had ever formed a conjecture. It seemed as if the Creator of the universe, by giving the telescope and microscope to man, desired that he should be made, in some degree, acquainted with the stupendous vastness and minuteness of creation."



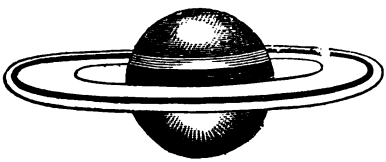
SCORPIO.

Thus ended the discourse of the astronomer.

CHAPTER XI.

NOVEMBER.

Another of those vast luminaries which revolve in the immensity of space is the planet Saturn, considered till lately as the farthest of all the planets, and distinguished from every other by a flat luminous ring extending round him. The diameter of this stupendous orb is about ten times, and his whole magnitude about one thousand times, that of the Earth: he revolves at an immense distance from the centre of our system, and hence the Sun presents to the inhabitants of Saturn not above one-eightieth part of his size or disc as *seen by* us: both light and heat are consequently much diminished. The



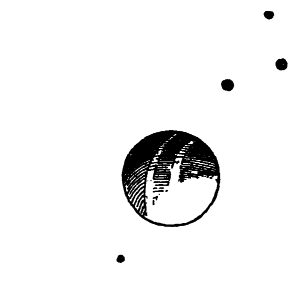
SATURN.

first is estimated by astronomers rather to resemble the light of the moon than that of the sun, though nearly five hundred times as much as the fair orb of night imparts when full, and the sky is cloudless; the second has given rise to many curious speculations, in reference to which a celebrated writer has conjectured that if a resident of that far-off world was suddenly conveyed to Lapland, he would be distressed with the heat, though surrounded with glaciers and snows that never melt.

Saturn journeys in his mighty orbit about twenty-one thousand miles an hour, and occupies nearly thirty years in passing round the sun. Ten hours and a quarter comprise his day; and this rapid motion has produced the same effect as in Jupiter, namely, a flattening of the poles, and a protuberance at the equator.

When Galileo first presented his telescope towards the planet Saturn, he discovered that his disc was not only crossed by obscure zones or belts, but that he was surrounded by an apparently solid ring, now ascertained to consist of two rings—one within the other, and having a dark space between them. Sir William Herschel, to whom we owe the knowledge of this remarkable fact, made known also that they reflected a stronger light than the body of the planet, and cast a shadow upon its disc. Seven satellites or moons were also seen to pass in their respective orbits around the planet, though distant, and comparatively but slightly luminous. Magnificent indeed must be the aspect of the heavens, as seen from Jupiter, with those pale beaming moons and a bright arch stretching athwart the firmanent, revolving around its earth in about ten hours and thirty-two minutes.

Those who look narrowly in a clear evening towards the constellation Aries may perhaps discern Uranus, by means of his bluish tint, though far remote in the solar system. He is in the constellation Aries throughout the month.



URANUS.

Uranus is a planet of no inconsiderable size; his bulk is eighty times that of the earth; his distance from the sun nineteen times further than our own, and he performs his annual journey in eighty-three years and one hundred and fifty days; this, therefore, is the year of Uranus, his summer half-year being upwards of forty-one times the length of that pleasant season which presents to us green leaves and fruits and flowers, and his winter half-year is equally long. The great luminary from which we derive both light and heat appears to his inhabitants, if such there be, not above $\frac{1}{400}$th of that which he seems to us, and consequently the light and heat received by Uranus are in the same proportion. Beings constituted like ourselves could not exist upon his surface, and yet we may conjecture that living creatures inhabit that remote planet, because six satellites or moons revolve around him.

These moons are distinguishable only by the highest telescopes. Two were readily marked out by Sir William Herschel; but the five others, together with the two innermost moons of Saturn, are the most difficult to discern among all the celestial phenomena.

Four small planets, called asteroids because of their semblance to stars, farther from the sun than Mars, but less remote than Jupiter, have been discovered since the commencement of the present century. They are called Vesta, Ceres, Pallas, and Juno; and concerning them we shall presently have occasion to speak more at large.

Men in olden times worshipped imaginary beings; turning from the adoration of the one true God, they adored the sun and moon, and often deified their fellow mortals, or creations of poetic fancy; hence the names of the four asteroids, and those assigned to the planets. Symbols were, moreover, attached to them, and such are their different characters:—

☉ Sun.	♄ Saturn.
☽ Moon.	♅ Uranus.
☿ Mercury.	⚴ Pallas.
♀ Venus.	⚵ Juno.
⊕ Earth.	⚳ Ceres.
♂ Mars.	⚶ Vesta.
♃ Jupiter.	

These names, derived from the "abominations—the idols of heathenism," are likewise associated with such of the metals as were known in older times, and with the days of the week.

We seek not to explain why gold and silver are connected with the sun and moon, when poets of all ages and of all nations have sung concerning the golden sun, and the silvery light of the fair moon. Mars—the sanguinary deity of that unhallowed art which has deluged the fairest fields with blood, namely, war—formed his weapons of destruction from iron; that metal, therefore, is associated with him. The planet Mercury, rarely seen, and then but for a short time, was named after the "fleet messenger of the gods," and identified with quicksilver. Tin was assigned to Jupiter, because the priests of Cybele, who are fabled to have tended his infancy in Crete, amused him with the clashing of their tin cymbals. Copper is connected with the name of Venus, worshipped in the island of Cyprus—that classic isle which supplied the civilized world with one of the metals earliest used by man for making vessels and utensils of various kinds, and which, when mixed with tin, produced a third metal, namely, bronze, more fusible, at the same time harder, and more serviceable for all common purposes. Lead may be regarded as the type of Saturn, in consequence of the dull and lead-like appearance of that planet.

By what means are those mighty planets which revolve around the sun prevented from rushing one upon another? Why is it that, self-upheld in the immensity of space, they ceaselessly revolve in their proscribed orbits? By virtue of that great law to which they yield implicit obedience—the law of gravitation; a law employed by Newton in determining the boundaries, distances, and movements of known celestial bodies, but which in the present age is used for discovering the existence of, and determining the distances and motions of unknown and hitherto invisible bodies. Hence it happened that the existence of Neptune was ascertained to a certainty before that remote planet was sought for; and which, by reason of his immense distance, can never appear otherwise than as a dim twinkling star, even by aid of the most powerful telescopes.

This was the mode of his discovery. Astronomers of old, as already noticed, contemplated the seven circling planets, which led their ceaseless dance around the sun, and poets sang concerning them. At length Sir William Herschel discovered the planet Uranus, or rather gave him a place among the planets; for he had previously been registered as a star by Flamsteed. Lalande shortly after determined his orbit to be an ellipse, and in consequence of remarkable and unaccountable perturbation in his movements, the Academy of Sciences at Paris proposed the subject as a prize question. Telescopes were accordingly directed towards Uranus, and eyes watched anxiously those slight deviations or irregularities in his path which are common to all planets, when acted upon by each other's attractions, in accordance with their relative positions. All this was readily understood; but movements which could not be accounted for continued slowly and uniformly to increase, till at length it was suggested that some unknown body revolved beyond the orbit of Uranus, and disturbed his action. The opinion speedily gained ground, and six astronomers confidently predicated that such was the case. M. Verrier, at Paris, and Mr. Adams, of Cambridge, undertook to solve the problem, although unacquainted with each other's intentions. They set themselves with unwearied diligence to find the place of an unknown planet in the heavens at a given time, "solely from the perturbations discoverable in Uranus at given points of his orbit." Our limits will not admit of following these astronomers in their calculations; suffice it, therefore, to observe, that they both arrived at the same conclusions, and that the planet was found exactly in the place pointed out by the French and English astronomers.

The difficulties which those gigantic minds had to overcome can only be appreciated by scientific men; the preliminary steps might have discouraged less ardent spirits, and the calculations would have baffled minds of no ordinary stamp. Every possible cause for the perturbation that first attracted their notice was carefully examined; all known planets and supposed comets were separately considered; while before them, as a mountain barrier, uprose the one great difficulty, viz., that the elements of the undiscovered planet were unknown, while the elements of Uranus, which could alone determine them, were erroneous by reason of, and from the action of, 'the unknown, though evidently existing body." The difficulty was, however, overcome, and a great triumph thus achieved leads back the mind to that highly gifted astronomer, immortal Newton, who first developed the existence of the great principle of gravitation, by aid of which the mighty problem was solved—a principle which, doubtless operating throughout the immensity of space, causes the planets to know their prescribed orbits, and to move in silent glory through the trackless heavens.

Nor is this the only discovery which science has unfolded—the only instance of astronomical research which sheds a halo on the present age: other planetary orbs have been brought to light, and such is a brief sketch of this wondrous discovery, abridged from the narrative of Sir David Brewster.

Within the boundaries of our own system, and in the vicinity of this earth, between the orbits of Mars and Jupiter, a wide space exists, which, according to the laws of planetary distances, ought to contain a planet. Kepler, the indefatigable astronomer of Wurtemburg, predicted that a planet would be found there, and his prediction has been fulfilled within a

comparatively recent period. Astronomers of our own times discovered, at the beginning of the present century, four small planets, to which they gave the names of Ceres, Pallas, Juno, and Vesta, occupying the very place in our system where the anticipated planet ought to have been found. D'Olbers, to whom astronomy was indebted for the discovery of Juno, suggested that they were the fragments of a ruined planet; and considering that in the tremendous explosion which rent a world asunder, they must necessarily have diverged from one point in the original orbit, and ought to return to the opposite point, he carefully examined those parts of the heavens, and thus discovered Vesta. The suggestion was not, however, acted upon for nearly forty years, but at length different astronomers aroused themselves to its consideration, and other planetary fragments were discovered; these fragments, successively discerned by the aid of powerful telescopes, received the names of Astræa, Stobe, Iris and Flora, Metas and Hygeia; and within a recent period a Neapolitan astronomer made known the eleventh fragment, which he called Parthenope. Admitting that these eleven small planets are fragments of a larger one, its size must have been very considerable; and how tremendous the awful catastrophe which burst into eleven huge fragments a world of glory and of beauty, inhabited, doubtless, by intelligent beings, passing, it might be, through a probationary condition of existence to one of inconceivable glory or of unutterable woe!

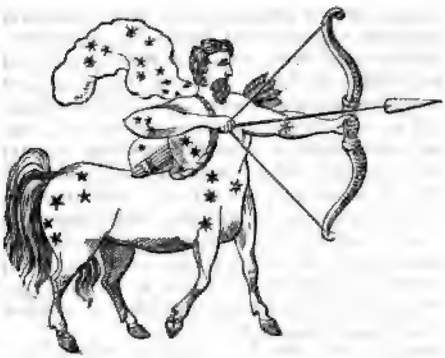
Astronomers spoke much concerning the strange discovery. By means of a law pertaining to the solar system, they determined the original magnitude of the lost planet long after it must have been shivered into fragments. This law was first suggested by Daniel Kirkwood, of Pottesville, an American in humble circumstances, who, like the illustrious Kepler, struggled hard to discover something new among the arithmetical relations of the planetary elements. A point exists between every two adjacent planets, where their attractions are equal; and if we call the distance of this point from the sun the radius of a planet's sphere of attraction, then the law by which Mr. Kirkwood sought to solve the important problem is simply this—"that in every planet the square of the length of its year, reckoned in days, varies as the cube of the radius of its sphere of attraction." The law thus ably applied has been verified by more than one astronomer, and admitted to be at least a physical fact in the mechanism of our system. This law requires the existence of a planet between Mars and Jupiter; it therefore necessarily follows that the broken planet must have been a little larger than Mars, or about 5,000 miles in diameter, and that the length of his day was about twenty-seven hours and a half.

Meditate on this important fact—on this brotherhood of planets, on their strange and mysterious origin. Rugged, torn, and probably desolate are they, rushing, though constrained in orbits which, by their intersection, bring them, as it were, like vessels at sea, within speaking distance of one another. How tremendous must have been the rending of mountains in the unknown globe of which we speak; the crashing of the hills, and the rushing of seas and rivers from out their ancient channels, when speaking thunders proclaimed that time should be no more, and hurled forth eleven enormous fragments on their career through the immensity of space!

Such was their doom—wherefore we know not. But for us a happier condition is prepared, even that the earth on which we dwell shall be

restored to its pristine condition of glory and of beauty at the termination of the present age.

Sagittarius, ninth of the celestial signs, represents that imaginary animal called a Centaur, with his bow drawn to its full extent, as if in the act of discharging an arrow. Neither the Chaldeans nor the Egyptians made use of this strange figure; the idea was most probably taken from the Parthians, who trained horses for battle; and being exceedingly expert with the bow, as well as swift in retreat, the emblem of a figure thus uniting both horse and man was judged the best representation of an archer. The figure of an arrow is occasionally seen on ancient obelisks, and is conjectured to be a hieroglyphical representation of this celestial sign, as also of expedition, the season of the year then rapidly speeding to a conclusion; or to the end of the sun's southern declination, when he again prepares to remount the heavens, and approach the equator.



SAGITTARIUS, OR THE ARCHER.

When the sun enters Sagittarius a change becomes perceptible. Forest trees generally lose their leaves about the beginning or middle of the month; if the wind is high, and the frost considerable, the defoliation often suddenly takes place; and he who, looking from his window, admires one afternoon a beautiful variety of mingling hues, sees next morning leafless branches, that display their elegant ramifications against the sky.

CHAPTER XII.

DECEMBER.

"What though not either voice nor sound
'Mid all the starry orbs are found,
In Reason's ear they all rejoice,
And utter forth a glorious voice,
For ever singing as they shine,
The Hand that made us is divine."—ADDISON.

LOOK up, look up! "One starry glitter girds the glowing pole!" Why do you walk with your eyes fixed on the ground, as if you were counting the pebbles by lamp or star-light, or else gazing listlessly around, when such

beauteous constellations are progressing through the immensity of space? Cepheus, Andromeda, Perseus, lead their ceaseless dance around the Pole-star; the head of the Great Bear verges on the meridian, with his magnificent square formed of four stars, and glittering tail in which Aliath holds a conspicuous station. Leo Minor crouches at his feet, and close behind, or rather as if seeming to menace him with his two good hounds, Boötes stands pre-eminent. Coma Berenices occupies a somewhat lower station; the head of Serpentarius gleams on the horizon; northward the Lion's skin and legs of Hercules appear, as if receding from the Dragon, who bears "a precious jewel in his head," called by astronomers Rastaben; near which uprises Lyra, with the brilliant star Vega. Deneb may be faintly discerned on the horizon, companion of the Swan, and shining as a beacon amid the sparkling luminaries that are everywhere conspicuous. Imagine the meridian line which seems to divide the starry heavens. Westward, yet near the north, appears Lacerta Stellio verging on the horizon; Andromeda comes next; and in the starry nucleus of most glorious forms, Cepheus and Andromeda, Perseus, with Medusa's head, and Cassiopeia, the "starr'd Ethiop's queen," as already noticed, bedeck the vault of heaven. The Lynx and Cameleopard verge on the meridian, and between the well-known constellations of Aries and Auriga the Triangle, Fly, and Pleiades may be readily discerned. Trace now the course of that starry belt which "men the zodiac call," and observe the beauteous order of the signs as they follow one the other. Aries comes first, harbinger in spring of budding leaves and lengthening days. Taurus succeeds, then Gemini, Leo, and Virgo with her spike. Below the ecliptic, and eastward of the meridian, a few stars, and those near the horizon, pertain to Lepus. Orion shines above them, resplendent in beauty, with his glittering belt; Canis Major is fully risen; Canis Minor apparently emerges from under the meridian; and between them Monoceres may be dimly seen. The ship Argo, recalling to memory days of wanderings and perils by land and sea in quest of the golden fleece, is barely visible on the southern horizon; and westward of the meridian line, beneath the ecliptic and skirted by the horizon, Hydra and Crater alone occupy a considerable space in the heavens, with the exception of Corvus, who may be faintly discerned immediately beneath the sign Virgo.

It is pleasant to be abroad, for the night is clear. Yonder is a shooting star, one of those swift and evanescent travellers which poets in all ages have loved to describe. Homer compared Minerva's hasty flight from the cloud-capped summit of Olympus, in order to break the truce that subsisted between the Greeks and Trojans, to the headlong rush of a shooting star. Virgil spoke of such as indicating a change of weather:—

> "And oft, before tempestuous winds arise,
> The seeming stars fall swiftly from the skies,
> And shooting through the darkness, gild the night
> With sweeping glories, and long trains of light."

But what are they, and whence do they proceed? Obscurity rests upon this question, however deeply interesting; for the phenomena of their existence must be referred to a cause exterior to the bounds of our atmosphere. At one time a single star seems to dart through the immensity of space; at another, a rush of luminous bodies becomes a subject of equal curiosity and conjecture. In the latter end of the seventeenth century

meteor passed over Italy, concerning which Montanari wrote a treatise. About forty years after a similar visitor was seen from every part of Great Britain, and formed the subject of one of Halley's papers to the Royal Society. Sir Hans Sloane spoke respecting it: "My path," said he, "was suddenly and intensely illuminated; I thought that the light proceeded from a discharge of rockets, moving with terrific celerity, and such unearthly brightness, that I was constrained to turn my eyes away." Astronomers who noted the sudden appearance of this strange visitant computed that it passed over three hundred geographical miles in a minute, at a height of sixty miles from the earth's surface.

Ancient writers speak concerning substances of unknown origin—gifts, said they, of the immortal gods, descending, without doubt, from Olympus. Such were the palladium of Troy, "the image of Diana, which fell down from Jupiter," as proclaimed Demetrius and his workmen, fearing that their craft would be in danger through the preaching of the Apostles (Acts xix.); the sacred shield of Numa; and the stone of Ensisheim, on the Rhine. Men have laughed at the credulity of the ancients; but however facts have been distorted, and a false halo shed by superstition on such meteoric wonders, modern writers have been constrained to renounce their scepticism with regard to the facts themselves. Meteoric stones have fallen in all ages, and unprincipled men, hewing and carving them into such forms as best suited their unholy purposes, sought, by such means, to impose on those who looked to them for guidance and instruction. But the days of simple credence have passed by, and Chemistry, touching with her magic wand mineral masses that have descended from the heavens, whether in India or in England, has discovered that their component parts consisted of seven different substances. Thus, for example, one of the stones that fell at L'Aigle contained—

Silica, ...	46 per cent.	Nickel	2 per cent.
Magnesia	10 ,,	Sulphur	5 ,,
Iron	45 ,,	Zinc	1 ,,

And terrible was the explosion which scattered huge stones over the fields of Caen, Falaise, Alençon, and L'Aigle. Labourers were working in the fields about one in the afternoon, the village matron plying her distaff, and young children playing before the cottage doors, when at once all voices were hushed, and the hearts of many failed them, for a fiery globe suddenly became visible, and hurried through the heavens with surprising swiftness; and as suddenly were heard three or four reports, like those of cannon, followed by a sound resembling the firing of musketry, succeeded by a seeming roll of drums. The heavens were clear, with the exception of a small rectangular cloud, motionless and compact; but this became diffused in all directions when the first loud report was heard, at which time there came a hissing noise, as of a stone discharged from a sling, and then down fell, with terrible impetuosity, a shower of stones, computed at nearly three thousand, and of which the largest weighed seventeen pounds and a half. Immediately after their descent they felt intensely hot, and were covered with a fused black incrustation, consisting chiefly of oxide of iron. And very curious is the fact, that although chemistry has not discovered in their composition any substance with which we were not previously acquainted, yet no other bodies have been found which contain the same ingredients

combined. Neither have volcanic products, whether of ancient or of recent date, exhibited a sample of those metallic and earthy substances which meteoric stones present. Few years have elapsed without a recurrence of similar phenomena; many have been recorded; others, doubtless, have occurred in those vast unoccupied regions of the globe where the scientific explorer alone identifies their existence. Pallas discovered an immense mass of malleable iron, mixed with nickel, at a considerable elevation on a slate mountain in Siberia; and in one of the rooms of the British Museum may be seen a specimen obtained from a similar deposit, which still remains on the plain of Otumba, in the district of Buenos Ayres; the specimen weighs 1,400 pounds, and the weight of the parent stone, which lies half imbedded in the ground, is at least thirteen tons. A similar block has been discovered in the province of Bahia, in the Brazils, weighing upwards of six tons; and, with regard to these strange substances, chemical analysis warrants the conclusion that their origin may be assigned to the same mighty causes that formed and projected the aërolites, which multitudes have beheld in their descent, and astronomers have recorded.

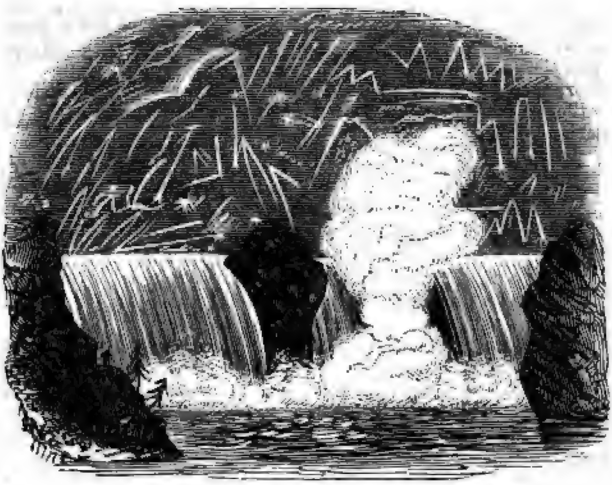
A tradition prevails in Siberia that the huge mass which rewarded the labours of Professor Pallas, by its discovery in a wild and isolated mountain, came down from heaven; and with regard to a metallic mass that fell in India, the Emperor Tchangire thus speaks of it in the memoirs of his reign: "A violent explosion was heard at a village in the Punjaub, and at the same time a luminous body descended to the earth. The officer of the district hastened to the spot where it fell, and finding that the place was hot, caused men to continue digging till they reached a piece of iron intensely heated. This was afterwards sent to court, and when weighed, was forged, by imperial command, into two sabres, a knife, and a dagger. This, however, was only effected by mixing the material with one-third part of common iron, previous to which the workmen reported that it was not malleable, but shivered under the hammer." The royal historian further adds, that when the "iron of lightning" was manufactured, a poet presented him with a distich running thus:—"During the reign of the illustrious Tchangire the earth attained order and regularity; raw iron fell from lightning, and was by his world-subduing word converted into a dagger, a knife, and two sabres."

Writers of the middle ages record the simultaneous descent of meteoric stones in resplendent showers; and chroniclers, both in the east and west, speak of similar coruscations. "It seemed," wrote a scribe who lived at Rheims, "as if all the stars in heaven were driven like dust before the wind." "And surely," recounts another, in the days of William Rufus, "by the reports of the common people, divers great wonders were seen; therefore the kinge was tolde by divers of his familiars that the Most High was not content with his livyng; but he was so wilful and proude of minde, that he regarded little that saying."

The first grand phenomenon of a similar description which attracted notice in modern times was witnessed by some Moravian missionaries in Greenland. Fiery particles, thick as hail, and presenting a magnificent and overpowering effect, descended over a wide extent of country. The whole heavens appeared to be illuminated with sky-rockets which darted in all directions, or as if some vast magazine stationed in unknown realms was

charging its fiery contents on the earth. Nor was the phenomenon con-
ed to Greenland. Humboldt, travelling in South America, spoke of its
nscending magnificence; a voyager at sea, beneath Cape Florida and the
est Indian islands, observed it also; the Capuchin missionary sojourning
San Fernando, a village amid the savannahs of Varinas, and Franciscan
nks near the entrance of the Oronoco, told concerning the astonishment
l terror which such a fiery deluge presented. Their concurring testimony
ves the fact of its having been visible over an area of several thousand
les, extending from the icebergs and frozen shores of Greenland to the
iator, and from the lonely deserts of South America to Weimar, in
cony, on the banks of the flowing Inn.

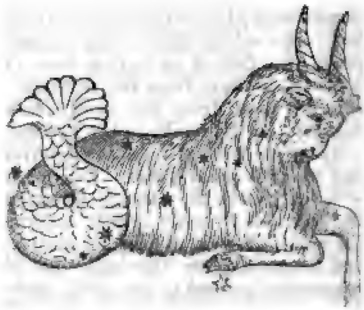
Fiery showers of a similar description have occurred at different periods,
l excited equal notice. One such included within the limits of the 61°
longitude in the Atlantic Ocean, and that of 100° in Central Mexico, ex-
ding also from the North American lakes to the West Indies, presented
most splendid display on record. Being the third in successive years,
l happening on the same day of the month as the two preceding, its
urrence seemed to invest the meteoric showers with a periodical character,
l originated the title of November meteors, in which month they have
n generally visible.



FALLS OF NIAGARA.

Our limits will not permit a more extended narrative concerning this
mendous phenomenon, which excited no small astonishment and fear.
r who could look unmoved upon unearthly fireworks playing over the
ad Falls of Niagara for several hours, during which one of the largest
teoric stones remained stationary for a considerable time athwart the
d torrent, emitting continual flashes, and lighting up the dark abyss

with unequalled sublimity? In many parts of the wide area over which the seeming coruscations flashed with such insufferable brightness, the utmost consternation prevailed, and shrieks of horror resounded on all sides. Such was the case in Southern Carolina; and we owe to an eye-witness the following affecting sketch:—"I was suddenly awoke at midnight by the most distressing cries that ever fell on mortal ears. While earnestly listening for the cause, I heard a faint voice calling me by name, upon which I arose, and taking my sword in hand, stood at the door. At this moment the same mournful voice bade me arise, saying, 'O Lord, the world is on fire!' I then opened the door, and it is impossible to say whether the awfulness of the scene, or the distressing lamentations of the negroes most excited me. At least one hundred lay prostrate on the ground, some speechless, others uttering the bitterest cries, and with uplifted hands imploring the Most High to save the world and them. The scene was truly awful, for never did rain fall faster or more heavily than the burning meteors fell towards the earth, east, west, north, and south."



CAPRICORNUS, OR THE GOAT.

Capricornus presents a singular appearance, and with his neighbour, Sagittarius, affords an exception to the general truthfulness of the zodiacal constellations.

PART VI.

TERRESTRIAL PHENOMENA

OF THE

MONTHS.

TERRESTRIAL PHENOMENA OF THE MONTHS.

CHAPTER I.

JANUARY.

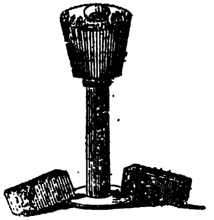
"All Nature feels the renovating force
Of Winter, only to the thoughtless eye
In ruin seen. The frost-concocted glebe
Draws in abundant vegetable soul,
And gathers vigour for the coming year.
What art thou, Frost? and whence are thy keen stores
Derived, thou secret all-invading power,
Whom e'en th' illusive fluid cannot fly?
From pole to pole the rigid influence falls
Through the still night, incessant, heavy, strong,
And seizes Nature fast. It freezes on,
Till morn, late rising o'er the drooping world,
Lifts her pale eye unjoyous. Then appears
The various labour of the silent night,
——————— the frost-work fair,
Where transient hues and fancied figures rise."—THOMSON.

THE most striking phenomena of the season are known to us under the names of FROST and SNOW. At this season it is usual to find the brooks—which lately prattled a mournful music amidst the naked trees, and bore upon their bosom towards the ocean the brown leaves of autumn—sealed up and congealed into silence. During the day a haze obscures the oblique rays of the sun, but at night the watery vapour being removed by the frost—

"The full ethereal round,
Infinite worlds disclosing on the view,
Shines out intensely keen; and all one cope
Of starry glitter glows from pole to pole."

The birds, which at other times found a plentiful supply of food in the open fields, find everything frozen and congealed into hard masses. The seeds and berries, which were formerly accessible to their horny beaks, are so no longer, owing to the freezing of the water in the ground, or the snow which hides their food. Hence the feathered tribes are driven by hunger to approach the dwellings of man, where the heat generated by fires, and radiated from his habitations, tends to thaw and soften the ice-bound surface around, and whence unfrozen nutrition is continually thrown at the doors. The wild fowl, driven from the chilly north, where the streams on which they were wont to swim are no longer liquid, take a southward flight, and in flocks of singular shape astonish the observer. The circumstance upon which these actions depend is the liability of water, when deprived of a certain amount of heat, to pass from the state of vapour or fluid to the solid form. Snow is watery vapour suddenly congealed, while ice is liquid water frozen. In passing from the liquid to the solid form, water is a remarkable exception to the law that all bodies expand when heated, and contract when

escape, the bottle will be burst by exposure to heat or to cold; for both would increase the volume of the liquid. From this it follows, that ice is lighter than water at any temperature below 48° of Fahrenheit's thermometer, and it will be shown that this increase of volume produced under the influence of frost is a most beneficial arrangement of the Divine Ruler of all things. If water, like other liquids, continued to contract and to increase in density until it assumed the solid form, our lakes and large bodies of water, instead of being superficially frozen in winter, would be hardened into solid masses of ice. The heat from the lake is abstracted by the cold winds which blow over its surface; and the chilled particles, being more dense, would descend, allowing other and warmer portions of the water to rise, and be exposed to the frosty air, till the whole mass of the water was reduced to 32°, when it would suddenly freeze, to the destruction of most of the living things therein. But this is prevented by the phenomenon of which we have been speaking; for, as soon as the whole mass is cooled down to 40°, there is no changing of position in the particles, since those on the surface which are rendered colder now become lighter than their fellows; so that the cold water actually floats upon that which is comparatively warm. Water being a bad conductor of heat, the warmth of the lower stratum is not removed, though the surface may be a sheet of ice. Moreover, ice being also a non-conductor, the cold winds may continue to blow without avail, since the deep strata of water are protected from cold, and remain at the temperature of 40°, whatever may be the cold of the surrounding air. To make this evident to the eye, the following experiment has been suggested:—Provide a small flower-pot, the upper part of which is from six to seven inches in diameter; then with a circular rasp enlarge the aperture of its lower part until it will just admit of the entrance of a cylindrical glass, two inches in diameter, and fifteen inches high, having a broad rest or foot at the base on which it may stand. The glass should be so placed in the aperture that its brim may stand a quarter of an inch above the level of the upper edge of the flower-pot. A yard of broad tape must be wound round the part of the glass which protrudes from the lower part of the pot, and this should be coated with a thick covering of plaster of Paris, in such a way that the joint may be water-tight. Having put the apparatus aside for an hour, to allow the plaster to set, it may then be placed in the position shown in the diagram, with two bricks upon its base to keep it from danger of falling.



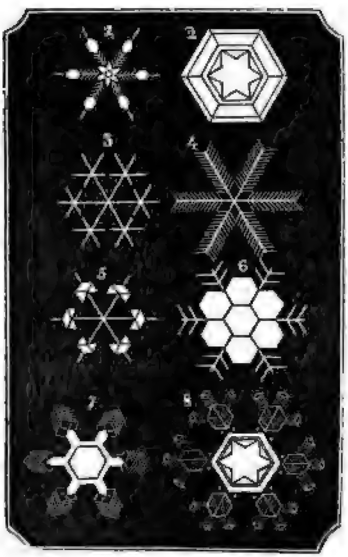
Carefully fill the space in the flower-pot with the mixture of ice and snow described above, so that none of the mixture falls into the glass; afterwards pour water of ordinary temperature into the latter, till it is filled within an inch of the brim. In this experiment we apply the cold, as in nature, *to the surface* of the water, and we shall find that though the surface may freeze, the water below remains at 40°, or 8° higher than that at the surface. If a delicate thermometer be immersed in the glass, it would indicate, first, that the *whole* of the water was reduced by convection to 40°, but that the currents then ceased; and that, finally, while the surface was freezing, the lowest portions were never colder than 40°. Having attained its greatest density, the process of cooling is no longer ex-

tended to the whole bulk, but is confined to that portion only in immediate contact with the freezing mixture. If the apparatus be emptied, and its parts re-arranged, so that the freezing mixture shall be applied to the lowest portion of the glass, we shall find that the whole mass of water will be converted into ice, for the cooling below 40° renders the water lighter; it ascends, while warmer particles descend, become cool, and in their turn re-ascend. Thus convection is established throughout the entire bulk of the water, and the whole of it is cooled down to freezing temperature, when it will become solid through its entire bulk.

Though the heat of water, when boiling, varies considerably in proportion to the density or rarity of the atmosphere, the freezing point remains always the same, and the chemist avails himself of this circumstance in the construction of the thermometer.

The expansion of water, which has been described, is the cause of the bursting of pipes and closed vessels during winter. It is related, indeed, that cast-iron bombshells, thirteen inches in diameter and two inches in thickness, having been filled with water, and their fuse-holes firmly plugged with iron bolts, were burst asunder when exposed to the severe cold of a Canadian winter; thus demonstrating the enormous internal pressure to which they were subjected by the expansion of water in freezing.

Herein we discover a most important agency, which produces great benefits to the husbandman. During the autumn and early winter months the soil receives into its interstices the water from the clouds, which creeps into every crevice in every clod; when frost comes, the water, expanding, pushes the particles asunder, and breaks the lumps into crumbling mould. The water, too, which during the long year has been collecting in some hidden cavity of the rock, suddenly, under the influence of cold, assumes a giant power, and hurls the mass from the mountain sides. The flagstones and pavements are tilted up by the same mysterious power, and flakes of the ornamental plaster on our walls are peeled off.



Ice has a great antiseptic power; that is to say, animal substances contained in it are prevented from decay. In 1803 the body of a mammoth—a race of animals now extinct—slowly appeared from a mountain of ice, in which it had been preserved from decay for several thousand years; the flesh was in excellent preservation, however, and was eaten by bears, wolves, and dogs with eagerness. During the winter, in the northern parts of Russia, meat is frozen and preserved in ice, and so sent to market in casks; and in Scotland salmon are packed in boxes with frozen water, which is an article of export from the lakes of North America.

We will now proceed to speak of Snow; and first let us observe how beautiul and varied are the forms of its flakes, when looked at through a magniying-glass or microscope.

How light and gracefully they fall, and how hilariously we greet the now storm!

"Through the hushed air the whitening shower descends,
At first thin wavering; till at last the flakes
Fall broad and white and fast, dimming the day
With a continual flow. The cherished fields
Put on their winter robe of purest white."

Iow beautifully the naturalist of Scripture describes it, too:—"As birds lying he scattereth the snow, and the falling down thereof is as the lighting f the grasshoppers; the eye marvelleth at the whiteness thereof, and the eart is astonished at the raining of it."

Snow is watery vapour suddenly frozen. Occasionally in Lapland the phenomenon of the formation of snow is witnessed when the door of an apartment n which persons are assembled is suddenly opened, and a blast of cold air dmitted, the watery vapour exhaled by their respiration being instantly rozen into flakes. Snow is a bad conductor of heat or cold, and therefore cts as a most valuable covering for vegetables and seeds: wheat continues o grow beneath its covering, though every blade would be cut off if exposed o the frosty air.

CHAPTER II.

FEBRUARY.

"Muttering, the winds at eve, with blunted point,
Blow hollow, blustering from the south subdued.
The frost resolves into a trickling thaw;
Spotted the mountains shine; loose sleet descends,
And floods the country round. The rivers swell,
Of bonds impatient. Sudden from the hills,
O'er rocks and woods, in broad brown cataracts,
A thousand snow-fed torrents shoot at once;
And, where they rush, the wide resounding plain
Is left one slimy waste."

"He giveth snow like wool: he scattereth the hoar-frost like ashes. He casteth rth his ice like morsels: who can stand before his cold? He sendeth out his words ıd melteth them; he causeth his winds to blow, and the waters flow."

There are not in nature any of those artificial divisions and distinctions hich men, for their convenience, have established. Though we speak of ay and night, of winter and summer, of spring and autumn; and though e may contrast the features of these periods, yet there is no point of time at hich we observe a natural division or line of demarcation between them. he daylight fades into twilight, and darkness spreads her cloak so stealthily, ıat we cannot say when she began "to hang her spangled mantle o'er our eads."

The light robes of spring slowly assume the gaudier hues of summer; ımmer insensibly fades into autumn; autumn unobserved is transformed

to winter; while from out the snows of winter peep spring flowers again. In like manner, we do not find that Nature is guided by the almanac in those changes of weather which are associated with particular months. If during a long course of time it was found that in January we had frost and snow; in February a thaw; in March wind; and in April that we were favoured with warm showers—we should naturally think of snow as the characteristic of January; of thaw as associated with February; of wind as connected with March; and we should expect to have a repetition of showers and sunshine in April. But there are no days on which the changes from frost to thaw, from stillness to wind, from settled to changeable weather, can be expected to occur. The beginning of each month usually resembles, in its terrestrial phenomena, its predecessor. We generally experience a continuance of January weather at the beginning of February, while at the end we are rejoiced to note the symptoms of approaching spring. At the beginning we have frost and snow, then comes a thaw, and this is commonly followed by the "piping strains of March," which begin to blow ere yet February has expired. The commencement of the month is wintry, but towards its close the crocus and snowdrop and the sallow show their flowers; the ringdove begins to coo, and the ants venture forth from their curious habitations; the new life of vegetation begins to be seen on warm sheltered banks. Hence the Saxons called February *Sprout-kele*, because the cabbage or kale then began to fill its buds. The woodlark and the thrush begin their songs, and "the rooks commence their political arrangements for their cawing session;" the mole enlarges his hunting grounds, and the field-crickets open their doors as if to invite the approaching spring.

Yet, for the most part, February is a slow, dull time to those who do not possess such sources of pleasure in themselves as to be beyond the depressing influences of foggy air, sloppy paths, and dropping skies. The weather seems to have all the discomforts of winter, without its compensatory advantages. The freshness of the frosty air, with its clear bright sky, no longer invigorates; a chilly mist hangs heavily in the atmosphere, and everything puts on a worn and melancholy aspect. The crisp snow has lost its brilliant whiteness, and has been changed by thaw to a sloppy mass, as unpleasing to the eye as it is ungrateful to the feet. The walls of the house are covered with moisture like a heavy dew, and the cold seems more penetrating than it was when the thermometer was five or ten degrees lower. The birds sit disconsolate upon the trees, and even the robin is less cheerful than usual. From the leaves of the holly and the ivy, and from the twigs of the blackened trees, drops of icy water are pendent, and the moisture which falls from the eaves freezes as it splashes on the ground.

Some years ago a number of observations were commenced, the object of which was to record the temperature—as indicated by Fahrenheit's thermometer—at certain hours every day, with a view to ascertain in what degree the average or mean temperature of any given month might vary. From these observations it was discovered that there was little variation in the average heat or cold of any month compared with itself through a long series of years. The mean temperature of February is 38° Fahrenheit, while that of January is scarcely 2° lower. The average temperature varies with position, and the observations to which allusion has been made apply only to the neighbourhood in which they were made. This variation of temperature is regular with reference to position; and the average

temperature of any place having been ascertained during ten years would be found to vary very little during the next ten years following. The climate of no two places can be said to be the same even in the same latitude, but the weather has certain general characteristics in every place every year. There is, therefore, a regularity in what appears most irregular.

The sun's heat is the chief cause of warmth on the earth's surface, but there is a supply of heat also from the central matter of our planet. As, however, the substance of the earth is an imperfect conductor, the warmth which is derived from the sun's rays penetrates nowhere above a hundred feet, and that which is due to the central heat produces little effect upon the crust of our planet. If we dig down about sixty feet from the surface of any part of the world, we find the strata there to possess the temperature of the average warmth of the climate of the country above them; if we dig deeper, however, we find the earth grow warmer as we descend, at the rate of about one degree of Fahrenheit's thermometer for every fifty-four feet. The principal causes of the difference in climate in countries appear to be—the amount of solar heat, elevation, position with reference to continents or seas or mountains, aspect, direction of prevailing winds, geological peculiarities, and the state of cultivation. In winter, in the northern hemisphere, we receive fewer of the sun's rays, and those during a more brief period than in summer. The rays of the sun, falling obliquely upon us, are, so to speak, spread out over a larger space than in the tropics, where they fall perpendicularly. From this cause, and also from the length of the tropical day, the temperature there is always high. The heat *derived from the sun*, therefore, decreases towards either pole. But the mean temperature, or general climate of any place, is affected in a great degree by the other circumstances which have been mentioned. For instance, since the higher we ascend from the earth the more rare the air becomes; and as, moreover, air so expanded requires more heat to warm it, so we shall find that the cold is greater the greater the elevation. Thus it happens that even in the torrid zone there are mountains capped with snow. In all parts of the world there is a point of elevation where snow would remain unmelted for ages. Places which are situated near large bodies of water have a less variable temperature than those which are situated in the interior of continents; for in summer evaporation makes the sensible heat latent in the vapour of water, while in winter that vapour becomes condensed, and gives out its latent heat to the air. Moreover, as previously described, when water is cooled, it becomes specifically heavier, and exposes its warm particles to the atmosphere, till its whole mass is reduced to 40°, thus supplying a steady source of warmth. Earth, on the other hand, rapidly absorbs heat, but transmits it very slowly; and so we find that the heat of the sun, accumulating in the crust of the earth, is readily given off by radiation. Hence places situated in the interior of continents experience great warmth in summer, and severe cold in winter. So remarkably are the differences of climate dependent upon situation, that we find the mean winter temperature of Edinburgh is 28·5°, while that of Moscow is only 15°, though these places are both in the same latitude. In our own climate the greatest heat is not at midsummer, nor the lowest at mid-winter; nor is noon the warmest part of the day, nor midnight the coldest portion of the night. This is because the warming influences, or the reverse, do not act immediately, but produce their effects *according to the time they are in operation*. The day is hottest

about two o'clock, and the coldest part of the night is that which occurs an hour before sunrise.

The aspect of any situation is well known to exercise a great influence upon its temperature, and the gardener makes use of his knowledge of this fact in placing his fruit-trees on the walls. That which is true of a garden wall applies, upon an extended scale, to the slope of a country or its aspect. Thus we find the climate at the same altitude on the two sides of the Alps of a strikingly different character—the one is sheltered from the northern blasts and exposed to the sun, while the other has a comparatively small portion of the sun-rays, and is chilled, moreover, by the cold winds from the north.

The lowest mean temperature is found, in North America, in 100° W. long., and in Siberia in 95° E. long. These are known as "poles of cold." The average temperature of the former is 3·5° Fahrenheit, and of the latter 1° Fahrenheit.

"Snow like wool" is not only correct as an ordinary metaphor, in which things alike in appearance are compared; snow resembles wool in its properties as a non-conductor of heat; and, indeed, nothing could be so well adapted to protect the earth "as with a garment" during severe cold, and yet so wisely contrived to pass away, and by its melting to fertilize the earth as soon as a warmer atmosphere is spread over the fields. It is recorded that "in Holland, during the winter of 1776, the surface of the earth was frozen to the depth of twenty-one inches on a spot of garden ground kept free from snow, but only to nine inches on an adjacent spot, covered with four inches of snow." The Esquimaux have discovered this quality of snow, and make use of it for building houses; and "when the lamps are lighted and the hut full of people and dogs, a thermometer placed on the net over the fire indicates a temperature of 38°; when removed two or three feet from this situation it falls to 32°, the temperature of the open air at the time being 25° below zero.

In the Arctic regions what is called "red snow" is sometimes found, and excites some alarm among the superstitious. It appears to be common snow coloured by oxide of iron, in a state of extremely minute division, and a vegetable principle, belonging to some lichen of a resinous character, and of an orange-red tint. The colouring matter is stated to penetrate to various depths, and is found to consist of exceedingly minute globules when examined under the microscope.

While snow is lying on the ground an interesting experiment may be performed, showing the different powers of colours to reflect or absorb heat. Procure some small pieces of kerseymere cloth of equal fineness and size, seven of them having the prismatic colours, and of the others one black and the other white. Lay them in the sunshine an inch apart upon snow, and leave them in that position for a short time; then observe how much the snow has melted beneath each piece of cloth, and how deeply each slip has sunk below the level of the surface. The black will be found to be the deepest, and the others in the following order—violet, indigo, blue, green, red, orange, yellow: the snow beneath the white cloth will be unaffected. By the aid of the information derivable from this experiment, we may answer the practical question—what colour is best adapted for clothing at particular times of the year, since it is evident that warmth or coolness depends not only upon the material of which our vestments are composed,

but also upon their colour? In sunny weather, when it is desired to keep the body cool, white clothing is to be preferred, because it reflects heat; while in winter, when all external heat is to be absorbed, and not reflected, the darker colours are to be chosen. Sensation long ago taught our ancestors these facts. Before passing from this digression, let it be understood that the rule which applies to inorganic or dead substances does not hold good in the case of the skin of the living negro, or the black coating which lines the back of the chamber of the eye, since it is found that the scorching power of the sun when received by *living* black surfaces is destroyed.

But why should snow be white? some may ask. If black and the darker colours of the solar spectrum be the warmest clothing, why was not that colour chosen for the covering of the earth in winter? The question is a natural one, but the answer is easily given. If snow had been black, it would have rapidly absorbed the sun's rays, and would have thawed beneath the first sunshine which fell upon it; the result would have been that the vegetation, prematurely deprived of that protection which was intended to guard it against the cold, would have died in the frosty air as soon as the sun had set. Moreover, we find that all living things perish under sudden alternations of temperature, though, if the change be made gradually, they can survive in curious extremes of heat and cold. We observe that a frost in spring, or in early autumn, generally does more damage to vegetation than the prolonged frosts and excessive cold of winter; because the sun's rays act quickly upon the unprotected frozen plants, and, by a sudden alteration in their warmth, induce a change inconsistent with their vitality. Hence gardeners who understand the philosophy of their employment take as much care to protect the objects of their attention from the sun's heat as from the frost's cold. The white, heat-reflecting, and non-conducting snow is the best protection against sudden alternations of heat or cold, for while it is melting its temperature never varies from 32°, and the vegetables which are enveloped in it rarely suffer a much lower, and cannot be exposed to a higher temperature.

Hoar-frost gives great beauty to the scenery of the winter months, and should therefore be noticed here. If a quantity of common alum or sugar be dissolved in hot water in a glass or porcelain vessel, and a number of strings or thin rough sticks be suspended in the liquid while cooling, it will be found that crystals of sugar or alum will be deposited upon the strings or sticks, before the smooth sides of the vessel show any marks of crystalline formations. This readiness, if we may call it so, of bodies assuming the crystalline form, to adhere to rough and porous substances in preference to such as are polished or compact, is observable in the crystallization of watery vapour which we know as hoar-frost. The tuft of hair scraped from the cow on the iron railing is covered with white fringes of frost-work, while the smooth metal has not a trace of crystalline deposit. The curled dead leaves, or the crumpled straws upon the pavement, have their edges adorned with white embroidery, while the surface on which they lie is unmarked by anything of the kind. When there is a very large quantity of moisture in the air these differences do not appear so clearly, and the hoar-frost deposits its "rime" upon all surfaces, though most thickly upon the rough and porous.

The beautiful and fantastic forms which dim the window-pane are also

crystals of water. The perspiration from the skin and lungs of the inmates of a room is condensed upon the glass which has given out a portion of its heat to the external air, and in turn withdraws a portion of the caloric from the watery vapour with which its internal surface is in contact. The vapour having lost that portion of its latent heat which was necessary to its existence in the gaseous form, resumes the fluid shape, and is deposited as dew upon the window-pane, where its temperature being still further reduced, it becomes solid, and gives to the eye the beautiful crystalline arrangement with which all of us are familiar. Amidst all these wonderful changes the water remains unchanged in its composition. To its various changes, and to the myriad processes to which it is necessary, are due, in a great degree, those natural phenomena which make the planet we inhabit so full of exquisite beauty.

CHAPTER III.

MARCH.

"Oh! a bard of many breathings
Is Wind in sylvan wreathings
O'er mountain tops, and through the woodland groves;
Now fifing, and now drumming,
Now howling, and now humming,
As it roves.

"Oh! are not human bosoms
Like these things of leaves and blossoms,
Where hallowed whispers come to cheer and rouse?
Is there no music stirring
In our hearts like sweet winds whirring
In the boughs?"—G. S. Philips.

Not many years ago, one day in March, a toddling child, who had spent the advent of its merry life in the busy rush of a far-spreading manufacturing town, and whose eyes had rarely been rejoiced by the smiling winsomeness of Nature in the fields and woods, ran into the room where we were sitting in a rural cottage, and clapping her hands, exclaimed with laughter and surprise—"Oh! mamma, come and look into the garden; the leaves are dancing, and the trees are clapping their hands." Such was a child's poetical description of the effects of the wind on the gaunt boughs of the tall trees, and the broad leaves of the stately evergreens. And verily all Nature seemed to waken up and be gay. The wind sang varied melodies as it rushed along, like a troop of spirits singing choral hymns of triumph.

"With a voice of thunder it tore through the leafless oak, while ever and anon it fractured its stalwart limbs, and seemed to laugh in triumph at its victory over the king of the forest. With a solemn bass it chanted through the sombre foliage of the cypress and the yew. With more martial music

t roared, like the defiant shoutings of a giant excited with wine, through the huge arms of the budding elm. With the sound of dashing billows it rushed through the poplar and the ash; while it went whistling piteously through the pliant willow. Like a mighty army of invaders, leaving desolation in its track, the vast mass of air, swifter than a bird, swept across the land, hurling every obstacle from its path." "The great struggle between Winter and Spring was over; and the former, with precipitous haste, fled from the combat, roaring, and raving, and howling away, vengefully leaving what ruins he could to indicate his power."

The most remarkable phenomenon of the month of March is WIND. Its boisterousness is proverbial:—"March comes in like a lion, and goes out like a lamb." The effects of the wind, too, have been noticed in the adages, "A peck of March dust is worth a king's ransom;" and, "The rooks have picked up all the dirt." The water in the earth, after having split up the clods of the mould under the influence of frost in January, was softened by the thaws of February, and sinking down into the crevices of the ground, has carried along with it the vegetable and animal matters which it had held in solution, and which are intended for the nourishment of the roots of plants. But the ground is yet too sloppy to receive the seed; the surface of the earth must be dried; the water must be evaporated from between the particles of soil: this it is the office of March winds to effect.

Wind is air in motion. The question then arises—What are the causes which are likely to produce such constant movement in a gaseous body like the atmosphere? It has already been stated that it is a general law that all bodies expand when heated, and contract when heat is withdrawn; and it follows that any cold substance (water excepted) containing, in an equal space, *more* particles, or atoms, than a warm body (in which the atoms are forced apart by the heat), will be attracted more forcibly to the earth, or, in other words, will be heavier. On the other hand, when any substance is rendered hotter than the medium around, it is attracted less forcibly to the earth, or becomes lighter. If a paper bag be constructed in such a manner that the air contained within it can be made warmer than the atmosphere surrounding the apparatus, it will be pushed upwards by the colder, and therefore heavier, air, which tends, as it were, to squeeze itself underneath the paper bag, or rarefied air-balloon. When a piece of cork is held under water, between the fingers, at the bottom of a vessel of water, its tendency to rise is owing to no peculiar property in itself, but is due to the water, which, pressing equally in all directions, forces upwards any substance having less attractive force than itself. The same phenomenon occurs when the fire-balloon ascends from the earth to a region where the air, from diminished pressure of gravity, is nearly as rarefied as the contents of the balloon. It is manifest, then, that whenever, from any cause, a portion of our atmosphere in its ordinary condition, unconfined, becomes expanded, a cubic foot of such portion will contain fewer particles than the same measure of air *not* so acted upon; and being attracted to the earth in a less degree, proportionate to the lessened number of its atoms, it will be forced upwards by the surrounding heavier air, which presses under it according to the laws of fluid equilibrium.

A current flowing towards the place from which the heated air has risen is thus produced, and a *wind* is said to blow towards that point. Heat being the common cause of the rarefaction of all bodies, it would be expected that

great conflagrations would produce upward currents of air, and strong wind blowing towards the fire; and we learn that these phenomena were remarkable at the burning of Moscow, where the cold air from the surrounding country blew from all quarters towards the city with the violence of a hurricane. The writer observed in the early morning, after a destructive fire in Manchester, that the weathercocks on the church spires and public buildings pointed in opposite directions from the scene of the fire, showing that there had been a stream of air rushing in from *all* sides towards the point of conflagration. The phenomenon upon a small scale is hourly to be witnessed in our houses. A fire is lighted in the grate, warming and rarefying the surrounding air, which, having a diminished attractive force, is pushed into the chimney by the heavier cold atmosphere, which squeezes itself through the crevices around the door and the window sash. What is called "a draught" in a house is a current of air produced by the pressure of cold atmosphere to displace that which has lost gravity by rarefaction.

The torrid zone—from causes already noticed—is the hottest portion of our globe, and here there must be the greatest rarefaction of atmosphere; there should, therefore, if our theory is correct, be an ascending current from this part of the earth, and winds blowing from the north and the south towards the equatorial regions. This is actually the case. The cold air from the frozen regions is continually pushing towards the tropics, while the heated atmosphere from the tropics forms an upper current towards the poles. The former produce the trade winds, so important to mercantile navigation, the latter act only upon the most elevated vapours. If the earth did not rotate, and local causes did not interfere, there would be throughout the northern hemisphere a steady wind from north to south; while in the southern hemisphere there would be a continuous stream of air from south to north. It is plain, however, that the air at the poles has a less rapid rotatory motion than that at the equator, and that the stream coming from the former latitudes will retain the slow movement which it there possessed. Now, we know that if we are driven rapidly (in a railway train, for example) against air which is quiescent, we have a sensation identical with that produced by wind blowing against us; and so, as the earth revolves from west to east, with a rapidity far exceeding the revolutionary rapidity of the air-stream, the latter appears to have an opposite motion, and seems to blow from the north-east in the northern hemisphere, and from the south-east in the southern half of the earth. While the cold currents from the poles are thus creating the trade winds towards the equator, the hot air which ascended from the tropics has parted with a portion of its warmth, and descends again at the poles, there producing a *west* wind, owing to the fact that this air possesses, in some degree, the more rapid rotatory motion of the equatorial regions with which it has been in contact. Hence south-west winds prevail in the north temperate zone, and north-west winds in the south temperate zone. It is on this account that the voyage from New York to Liverpool does not occupy on the average more than twenty-five days, while the average length of time occupied by the voyage in the opposite direction is about thirty-five days.

As the trade winds approach the equator, they begin to partake of the motion of the earth, and their *apparently* easterly direction becomes less and less; and in the immediate vicinity of the equatorial zone the air current seems to blow due north and south on either side.

Under the head of "The Terrestrial Phenomena of February" (p. 463), the various causes affecting the climates of different places are mentioned. It need scarcely be observed that all the agencies which affect the temperature of a locality will also tend to influence its air-currents. The extent of water or land, mountain ranges with summits above the snow line, and all other peculiarities of terrestrial aspect in the neighbourhood of a place, produce changes in the air-currents by which it would otherwise be supplied. Thus, in the Indian Ocean, the trade winds, whose general direction has been described, receive a curious modification from the position of the surrounding land, and the effect of solar heat upon it. The district in which this phenomenon—which is called the *monsoon*—is observed, extends from the east coat of Africa to about 135° E. longitude, and from the southern parts of Asia to about 10° S. latitude. From April to October, while the sun's rays are vertical on the northern side of the equator, and the surface of the continent there highly heated, a S.W. wind blows from 3° S. latitude, over the northern parts of the Indian Ocean, Hindostan, the China-Indian states, and the Indian Archipelago. Over the same districts, during the remaining part of the year, a N.W. wind prevails. From the third to the tenth degree of S. latitude there is a S.E. wind from April to October, and a N.W. during the next half-year. The S.W. wind brings in the "rainy season" of India.

The trade winds and monsoons may be considered *regular* winds, being subject to little variation from year to year in the recurrence of their operations. The larger the expanse of ocean over which the former blow, the more steady is the air-current; and for this reason the trade winds are found to be more continuous and invariable in the Pacific than in the Atlantic Ocean, and in the South than in the North Atlantic Ocean. It is singular that in the region of the constant trade winds rain falls very seldom, though there is an abundant supply of frequent showers in the adjoining latitudes. The cause of this will be explained in connection with the phenomena characteristic of one of the later months.

The rapid changes and extreme variations of temperature liable to occur in extensive tracts of land, render the winds more uncertain in such localities, and their phenomena less reducible to order, so that no general law can with certainty be derived from the observations which have been made. Even in equatorial latitudes, under such circumstances, there is little constancy in the direction or intensity of the winds. In high latitudes the inequalities are still greater, and extend even to the open seas; and, indeed, the winds seem to obey no fixed laws beyond the latitude of 40°. There are, however, in all latitudes gentle winds on the borders of the ocean, called *land* and *sea breezes*, which should be noticed and explained in this article upon "Wind." During the day the rays of the sun warm the surface of the land to a greater degree than that of the adjacent ocean, and the air above it, being rarefied, is displaced by the denser air rushing in from the sea; hence a current, or *sea breeze*, begins to set in soon after sunrise, and continues to flow towards the land till after the rays of the sun have ceased to supply caloric. In this country the sea breeze sets in about seven or eight o'clock in the morning, and continues (according to the season) till three or four o'clock in the afternoon. When the sun has sunk beneath the horizon, the earth, by radiation, rapidly parts with the heat it has absorbed, and becomes colder than the water; and then the air above the land having

become more dense, and consequently heavier, pushes the sea air aside, and thus creates a *land breeze* blowing from the coast towards the ocean. Every person who has visited the sea-coast has had opportunities of noticing these phenomena.

It will hardly be appropriate here to describe the winds which are peculiarly local, such as the suffocating wind of Arabia, Egypt, Syria, &c., known as the Simoom; the dreadful Sirocco of Sicily; the scorching Solano of Spain; the withering Harmattan of Africa; or the freezing Bize which visits the districts at the foot of the Alps. It has been our intention only to deal with phenomena which illustrate and prove certain general laws.

The velocity of the wind varies from an imperceptible current to a hundred miles an hour. When its rate of movement is about five miles an hour, it is said to be a "pleasant breeze;" when its speed rises to thirty miles an hour, the wind is described as "high;" when it gains a force of double that rapidity, a "great storm" results; and when its velocity rises to eighty or a hundred miles an hour, the most dreadful destruction of trees and houses ensues, and a "hurricane" is said to occur.

Having described, in general terms, the causes of winds and some of the most remarkable air-currents, the reader will expect to learn somewhat of the effects of these phenomena. For what good end do winds blow? We have a firm belief that all such things must have a beneficial purpose to which they are specially adapted. What is the purpose of the winds? What is the especial duty of the currents from the pole to the equator? The first thing which strikes us, perhaps, is the difference in the temperature of the two latitudes just named; and we should not erroneously conclude that one effect of these air-currents was to tend to equalize their temperature, by conveying the cooling atmosphere of the frozen regions to the tropics, and *vice versâ*. But another and more important relation between the poles and the tropics is kept up by the agency of wind. In the districts where extreme cold prevails, a greater quantity of carbonic acid is given off by the lungs, while the vegetation, being stunted, has less power of decomposing the poisonous gas and eliminating oxygen than in the torrid zones, "where a sky, seldom clouded, permits the glowing rays of the sun to shine upon an immeasurably luxuriant vegetation," and where oxygen is given out abundantly. Between these regions the winds effect an interchange, conveying the carbonic acid of the poles to the tropics, and the oxygen of the torrid zone to the frozen regions. Wind, moreover, is of great use in drying the earth in seed-time, &c., by the process of evaporation; it is also the agent which conveys the clouds from the waters over the lands; and it exercises a constant influence in preventing the stagnation of the atmosphere, and in the dispersing of noxious effluvia.

It is due to the reader to mention that although heat is the chief cause of atmospheric disturbances, yet that the rapid condensation of vapours in the atmosphere occasionally produces sudden and powerful air-currents. Sufficient rain to form a layer of water an inch in depth has been known to fall in the equinoctial regions over a large extent of country: the liquid was previously in a state of vapour, occupying much greater space, and upon its condensation a vacuum would have been produced if the air from all sides had not pressed in to fill the empty space. Suppose the superficial extent over which rain had thus fallen to be one hundred square leagues—if the vapour necessary to produce this quantity of water existed in the atm

sphere at a temperature of 50° Fahr., it would occupy a space one hundred thousand times greater than in the liquid state. The immense void resulting from such a condensation may be conceived, and an idea formed of the mode in which violent atmospheric concussions are produced. The whirlwinds, which produce such disastrous effects in the tropics, are believed to be caused by these sudden condensations of vapour.

CHAPTER IV.

APRIL.

"Thou visitest the earth, and waterest it. * * * Thou makest it soft with showers; thou blessest the springing thereof."—*Psalms.*

"When proud pied April, dressed in all his trim,
Hath put a spirit of youth in everything."
SHAKESPEARE'S *Sonnets.*

"Next came April, wanton as a kid."—SPENSER.

"The effusive South
Warms the wide air; and o'er the void of heaven
Breathes the big clouds with vernal showers distent.
At first a dusky wreath they seem to rise,
Scarce staining ether; but by swift degrees,
In heaps on heaps, the doubling vapour sails
Along the loaded sky, and, mingling deep,
Sits on th' horizon round, a settled gloom:
Not such as wintry storms on mortals shed,
Oppressing life; but lovely, gentle, kind,
And full of every hope and every joy,
The wish of Nature. * * * * At last
The clouds consign their treasures to the fields,
And softly shaking on the dimpled pool
Prelusive drops, let all their moisture flow,
In large effusion, o'er the freshen'd world;
The stealing shower is scarce to patter heard
By such as wander through the forest walks,
Beneath the umbrageous multitude of leaves.
* * * * *
Thus all day long the full-distended clouds
Indulge their genial stores, and well-shower'd earth
Is deep enrich'd by vegetable life."—THOMSON'S *Seasons.*

STURM, in his delightful "Reflections," says that the nearer we approach this charming month of April, "the more we see the wild and melancholy appearance of winter wear off. Each day brings forth some new creation; each day Nature draws nearer to perfection." "Nature is dressed in smiles. Spring has donned her robes of brightest green, and uprises like a joyous

bridegroom to meet the beauteous Summer in her bowers. All above, like white and downy feathers, the fleecy clouds are cradled in the sky, rocked by singing zephyrs, or sail along like fairy ships upon an azure ocean. All below is spread a fresh and gorgeous tapestry of green, inwrought with golden threads of cowslips, primroses, and celandines, and jewelled by azure speedwells or delicately-tinted cuckoo-flowers; while here and there the daisy—childhood's dearest ornament—peeps up with childlike modesty, pouting its budding lips in rosy eagerness to kiss the young year's feet as they pass along, glistening with diamonds of scented dew. The sky weeps tears of joy, wooing the earth to fruitfulness."

Everybody, from young Shakespeare to the latest school-child, loves the month of April—its blossoms, its skies, its playful breezes, its scented showers. Sobered by passing years, as we sit in our study penning these lines, we catch again the spirit of our boyhood's springtide, and while we write we live again in that happy time. As then with delighted feet we dashed among the primroses and violets; so now, in imagination, we would revel among sweet woodland scenery, and treat of buds and blossoms, with a poetry belonging to a bygone era of our life. But this is not a part of our present plan, and it is due to our readers to refuse to deviate from the path along which we have undertaken to conduct them, though sweet flowerets, redolent with teeming memories and sweet associations, lure us from the way.

The winds of March having dried the surface of the earth, the mould is rendered friable, and fitted to receive the seed from the hands of the husbandman. But moisture is necessary to the germination of the seed, and no sooner is it deposited in the soil than April showers come with warmth and geniality. The rain that seems to fall capriciously is wisely and benevolently sent, and gives the character to the month as the most remarkable terrestrial phenomenon occurring during its passage. If we could in sensations be children once more, and feel again the marvellous astonishment we experienced when first we saw water come pouring from the sky, we should be able to understand how really wonderful and beautiful is an ordinary shower of rain. But familiarity has destroyed the perception of its marvellousness, so the world shoulders its umbrella, and goes sulkily on its way. Let us not follow the fashion, nevertheless, but stop to inquire what is the cause and nature of a shower of rain.

The first question which arises is—How did the water accumulate in the air to form the rain-drops? Whence came the fluid, and how did it ascend into the sky? These questions may, perhaps, be answered by others. If a few drops of water are poured and spread upon a slate, and left exposed to the air, they will shortly disappear: what has become of them? The water is said to have *evaporated*, or to have passed away in the state of vapour into the air. Of this property in air to cause a gradual wasting away of the surface of water we shall have to speak hereafter; we mention it here only to afford a clue to the origin of the water which falls as rain. From lake, river, sea, and ocean, the process is continually going on, and is active in proportion to the temperature of the air, its dryness, and motion. If on a hot summer's day two bowls of exactly equal capacity be filled with water, the one exposed to the sun's rays and a current of air, while the other is placed in a cold cellar, the former will be found to have lost a considerable portion of its contents, while the other remains unaltered. If the air be

heated, its capacity for water is increased; if it be suddenly cooled, the vapour is condensed, having parted with the latent heat which was necessary to preserve its rarefied condition. If, moreover, as soon as any portion of air is saturated or loaded with watery vapour, it is displaced by fresh dry air, the evaporation will be more rapid than under ordinary circumstances. Thus, under the influence of wind, the moisture of the earth is carried off with extreme rapidity. The water which by this process rose upon the wings of the wind in March, as an invisible vapour dissolved in the air, becomes condensed again in April, to fertilize the earth from which it originally proceeded.

Let us verify this by experiment. When the kettle boils we observe that steam or watery vapour issues from the spout. At first the atmosphere doe not dissolve it; and while this is the case it is visible to the eye. Before, however, it has been driven many inches from the vessel the steam disappears, and "vanishes into thin air." After this has gone on for a time, if the vapour be generated fast enough, the air ceases to be able to absorb, and a mist or steam is perceived in the apartment. While the air is yet transparent—that is to say, while it retains its power of absorbing watery vapour—the fluid which passed from the kettle may be regained and made visible. A certain portion of heat supplied by the fire to the kettle was required to convert the liquid into vapour; the sensible heat became latent. Since this heat is necessary to the permanence of the vapour, it is plain that if it could be withdrawn the steam would return to its original form, fluid. This may be accomplished as follows:—Place upon the table of the room where the steam has been generated one of the tall cylindrical glasses used by the confectioners, capable of holding rather more than a pint. Take care that the outside is perfectly dry, and that the vessel is cool. Throw into the glass a mixture composed of five ounces of muriate of ammonia (sal ammoniac), five ounces of dry nitrate of potash (saltpetre), and eight ounces of sulphate of soda (Glauber's salts); pour over the powder a pint of the coldest water that can be procured, and stir gently with a glass rod or bone paper-knife. A large amount of heat will be absorbed by the mixture, and the air contiguous to the sides of the vessel will be cooled to such a degree that a portion of the vapour contained in it will be condensed and precipitated upon the sides of the glass, like drops of dew. In the same manner, we may observe that the moisture of heated rooms is condensed upon the window-panes when the air without is cold; and after a thaw, when the air is warmer than the walls of our houses, a similar deposit of water takes place.

The temperature at which the condensation of watery vapour begins is called the *dew-point*, and many ingenious instruments have been devised to ascertain the quantity of steam contained in the atmosphere at any particular time, by noticing the point on the thermometer at which dew is formed. We say the air is *dry* when water is quickly dried up, or absorbed by it; on the other hand, we say the air is *damp* when wet substances dry only slowly. In the former case a greater degree of cold would be required to precipitate the water, or condense the vapour; while in the latter the slightest reduction of temperature would induce the re-formation of water. When the condensation of vapour in the air, under ordinary circumstances, occurs by contact with cold solid bodies, it is called *dew;* when, on the contrary, the whole body of air is cooled, *mists*, *clouds*, or *rain* are formed.

The vapour of which clouds are composed, and which supplies the fluid to

the showers of April, is in a peculiar condition. A scientific traveller on the Alps describes the appearance of a mist by which he was enveloped, and which was almost stagnant. He was greatly astonished at the size of the drops, as he imagined them to be, the more especially when he saw them float along without any tendency to fall to the earth. These bodies, which were of the size of the largest peas, proved, upon investigation, to be vesicles, or small bubbles of water of extreme tenuity. It is considered probable that in clouds and mists the fluid is always in this singular condition, though there may be great differences in the size of the vesicles. If clouds, mists, or fogs consisted of drops, they would immediately fall to the earth; indeed, it has been calculated "that a drop of water, one thousandth part of an inch in diameter, in obedience to the action of gravitation, would acquire a descending velocity equal to nine or ten feet per second; whereas we see clouds hover at a small elevation for hours. It is probable that this vesicular condition of water is produced when two volumes of air of different temperatures, and in different electrical conditions, meet and mix together. If this, however, takes place too rapidly, drops, instead of vesicles, are formed; or when the stratum of air in which the vesicles float is suddenly condensed, the separate globules approach each other and merge, and a fall of rain is the consequence.

It must be admitted, nevertheless, that the exact circumstances which produce the vesicular state of water are not known, nor are scientific men prepared to state positively what conditions are necessary to its permanence, or its change into the form of rain-drops.

Some extraordinary falls of rain have been recorded: on the 25th of October, 1825, a fall of rain equal to the depth of thirty-two inches fell in twenty-four hours at Genoa; on the 9th of October, 1827, there fell at Joyeuse, in the south of France, thirty-one inches in twenty-two hours. A curious circumstance attending the fall of rain is that the quantity collected by rain-gauges, or instruments used for registering the depth of water which falls, varies in an unaccountable degree with the elevation of the instruments. The quantity collected by rain-gauges on the surface of the ground is considerably greater than when the instruments are placed at some elevation above. On an average of thirteen years the quantity of rain which fell annually in the *court* of the Observatory at Paris was twenty-two inches; while the mean quantity which fell on the terrace, ninety-two feet above the level of the court, was less than twenty inches. A rain-gauge placed at the top of York Minster showed a fall of nearly fifteen inches between February, 1833, and February, 1834; while another perfectly similar instrument on the ground registered nearly twenty-six inches. The cause of these singular discrepancies is not understood, but is supposed to depend upon the currents of wind, which interfere with the perfect actions of instruments elevated from the ground.

The average quantity of rain which falls in a year in any given place depends upon a great variety of circumstances, principally those connected with climate, &c., which have been explained in a previous month.

The sky is usually overcast by a dark cloud before a shower, but instances are on record where rain has fallen from a serene, cloudless sky. This curious phenomenon is said to occur frequently in the island of Mauritius in the evening, when the stars are shining; it has also been observed in Paris, Geneva, and Constantinople.

In tropical regions the rains are periodical, as before mentioned; they fall only at certain seasons, and for an hour or two daily. The drops are said to be larger than those which we are accustomed to see, and owing to their greater weight, strike the earth with considerable violence. "The morning is clear, the clouds gather towards mid-day, heavy rains fall in the afternoon, and the evening is again clear and fine. At times the sky is unclouded for months together."

Rain is unknown in some parts of the world, viz., the arid deserts of Africa and Arabia, the deserts of Gobi, parts of Mexico and California, and the west of Peru.

From numerous observations it has been proved that the mean or average annual temperature generally occurs on the 24th of April and the 21st of October in the temperate zone.

In England the course of the heat is as follows:—The temperature rises from the middle of January until the middle of July, from which period it diminishes, finally reaching its minimum again in the middle of January.

> "April, at whose glad coming zephyrs rise
> With whisper'd sighs,
> Then on their light wing brush away,
> And hang amid the woodlands fresh
> Their aëry mesh,
> To tangle Flora on her way.
>
> "April, it is thy hand that doth unlock,
> From plain and rock,
> Odours and hues a balmy store,
> That breathing lie on Nature's breast,
> So richly bless'd,
> That earth or heaven can claim no more."—BELLEAU.

CHAPTER V.

MAY.

"Fair-handed Spring unbosoms every grace,
Throws out the primrose and the snowdrop first;
The daisy, primrose, violet darkly blue,
And polyanthus of unnumber'd dyes;
The yellow wallflower stain'd with iron-brown,
And lavish stock, that scents the garden round;
From the soft wing of vernal breezes shed,
Anemones; auriculas enrich'd
With shining meal o'er all their velvet leaves,
And full ranunculus of glowing red.
Then comes the tulip race, where Beauty plays
Her idle freaks; from family diffused
To family, as flies the father-dust,
The varied colours run; and while they break
On the charm'd eye, the exulting florist marks,
With secret pride, the wonders of his hand.
No gradual bloom is wanting—from the bud,
First-born of Spring, to Summer's musky tribes;
Nor hyacinths of purest virgin white,
Low bent, and blushing inwards; nor jonquils
Of potent fragrance; nor narcissus, fair,
As o'er the fabled fountain hanging still;
Nor broad carnations, nor gay spotted pinks;
Nor, shower'd from every bush, the damask rose.
Infinite numbers, delicacies, smells,
With hues on hues expression cannot paint—
The breath of Nature, and her endless bloom."—THOMSON.

"In April come the double white violet, the wallflowers, the stock-gilliflowers, t cowslip, and lilies of all natures; rosemary flowers, the tulip, the double peony, t pale daffodil, the French honeysuckle, the cherry-tree in blossom, the damascene, a plum-trees in blossom, the white thorn in leaf, and the lilac-tree."—BACON.

THE wisest and best of men have ever entertained a passionate love flowers. The poet-king of the Hebrews was evidently an ardent lover nature, and familiar with the phenomena passing around him. "Let flower," he exclaims, "let no flower of the spring pass by us: let us crow ourselves with rosebuds before they are withered!" And his writings tee with illustrations derived from the beauties of nature around him. modern times we find philosophers and poets with the same love of t exquisite productions of the early year—the flowers of May. With wh joy old Spenser seems to write:—

"Then came fair May—the fairest maid on ground—
Deckt with all dainties of her season's pride,
And throwing flowers out of her lap around."

And Herrick, too:—

"Oh, May, with all thy flowers and thy greene,
Right welcome be thou, fair fresh May!"

To quote from Shakespeare would be truly "love's labour lost;" for eve page is redolent with "the breath of flowers," which, as Bacon observe

"comes and goes like the warbling of music." How the mighty Milton, "from his eminence aloft," sweetly discourses of the denizens of the meadow and the wood, and rejoices over—

> "The flowery May, who from her green lap throws
> The yellow cowslip and the pale primrose!"

And lesser poets, down to Wordsworth, Tennyson, and Longfellow, revel in their love of flowers.

Our Lord and Master sought in the flowers and fields the poetical illustrations of the arguments which he wished to enforce, and in so doing appealed to a strong perception and love of the beautiful, which is common in every land where Nature is prodigal of floral beauty. "Consider the lilies of the field," said he, "how they grow; they toil not, neither do they spin: and yet I say unto you, that Solomon in all his glory was not arrayed like one of these."

Since May is the festival of flowers, the gay-day of the vegetable kingdom; and since all, from the youngest to the oldest, never think of the time apart from its blossoms and sunshine, leaves and fragrance, we shall, in this chapter, "consider the lilies of the field, how they grow." A greater familiarity with the denizens of the meadow and the wood will not diminish the love we have hitherto felt for them, but will add to our list dear acquaintances whose faces will greet us as in our solitary walks, peeping from the hedge-side, or by the forest path, to remind us of the ever-watchful care which strewed the waste ground with flowers, and covered the desert island, and even the rock, with life and beauty.

It is manifest, as plants are not exactly alike, that it is convenient to name them differently; but it is also plain that as in some points certain plants resemble each other very closely, it is desirable to group such plants ogether, and give them names which imply their relationship. This nomi- al division of the vegetable kingdom into families and orders is necessary, f we seek to gain any general idea of its parts, because it would be quite mpossible for any one person to have a detailed knowledge of each indi- idual plant, separately considered, without its relations to others. A imilar kind of division is found convenient in almost everything. The untry is divided into counties, hundreds, &c.; the legislative body into ords and Commons; the school into classes and divisions. The surface of e world is artificially divided into sections, by lines of latitude and longi- de; the stars are considered in groups. Knowledge is divided into arts d sciences; and science, again, is subdivided into geology, geography, &c. ivision and arrangement are necessary to the consideration of every part of e vast field of nature, and as the vegetable kingdom consists of upwards 100,000 species, it is especially convenient to those seeking to become tter acquainted with inanimate life.

In calling attention, then, to flowers and their growth as the most re- arkable phenomena of the months of May and June, we propose to consider e best method of becoming acquainted with their nature and properties; , in other words, what system of classification it is best to adopt in the dy of botany.* But to do this we must possess some information with

* The word is derived from βοτανη, a plant; the root of the Greek word signifies o feed."

regard to plants, such as the names of their parts, and the functions which those parts are intended to perform. We shall not now pause to consider the difficulty which exists in drawing a line between the animal and vegetable kingdoms, but proceed at once to speak of what are well known as plants. Of these objects the most familiar part is the leaf; and it is remarkable that all other parts, except the roots and their appendages, can be shown to be no other than transformations of this organ; as a proof of which it may be observed that petals, stamens, &c., are liable to reassume, under peculiar circumstances, a leafy character. The transformations of stamens into petals is a common change, and is that which converts single into double flowers; hence, as the stamens perform an important part in fructification, thoroughly double flowers produce no seeds. This theory—that all appendages of the ascending axis, or stem, are leaves metamorphosed to serve particular purposes—was originally suggested by Linnæus, but afterwards more fully expounded by the illustrious German poet, Goëthe. The first growth from the seed is leaf-like, and following it come true leaves, and from a succession of these the stem is developed; from the sides of the stem, buds—which are bundles of folded leaves—arise; and from a series of buds the branches proceed. When a certain degree of maturity has been attained by the plant, the leaves upon portions of the stem, near the point at which flowers are about to appear, assume an altered character, and become smaller and more petal-like: such leaves are called *bracts*.* They are seen on the stem of the rhubarb, are very remarkable objects in the lime-tree, and may be easily found on many common plants. Bracts may, in general terms, be defined to be the leafy appendages between the true leaves and the flower. There are some plants, however, in which they are not found, and many in which it is difficult to distinguish them from parts of the flower itself; as, for example, in the common daisy, where the narrow green leaflets which are so neatly folded over each other, at the back or base of the flowers, are *bracts*—not parts of the true blossom.

It will be convenient if, before we proceed further, we go into the fields and gather a plant—the more common, the better adapted will it be for our purpose, because there will be the greater probability that all our pupils will be enabled to procure specimens; and they will learn, moreover, at the same time, that the most useful and amusing knowledge may frequently be derived from objects with whose outward appearance we have been for life thoroughly familiar.

Who does not know the bright-flowered buttercup? Which of us has not, in joyous infancy, gazed upon its polished golden petals with a feeling of pure delight that in later years we seldom or never know? The buttercup—dear jewel-flower of childhood!—associated with its sweet companion, the modest daisy—what can be more fitting subjects for maturer thought than these, the earliest objects of baby admiration? Let us, then, consider these two familiar friends attentively. In the buttercup the natural leaves consist of many divisions, while in the daisy the leaf is in one piece; in both leaves, however, we find the veins or fibres, of the leaf distributed upon a somewhat similar plan, viz.,

* From the Latin word *bractea*, a thin leaf of metal.

a central, or principal fibre, from which smaller fibres arise, and form a network of veins on either side. On cutting the stalks, moreover, and examining them with a magnifying-glass, we discover a further similarity of structure; for we see that there are bundles of woody tissue symmetrically arranged around a central pith (*d*).

Fig. 1.

Above the bracts we find the blossom, which consists of the following parts:—1. Calyx; 2. Corolla; 3. Stamens; 4. Pistil. If we look at the base or back of the buttercup, we shall observe five small green leaves, as it were, supporting the yellow leaves of the blossom (Fig. 2, *b*). Each of these green leaves is called a *sepal*, and the five sepals together form what is called the *calyx*, because they are frequently united at their edges, and thus constitute a cup (calyx) for the flower. Within or above the calyx we have five yellow *petals*, which together form the *corolla*, a word that signifies in Latin a little crown or garland, and has been applied to this part because the petals (the parts of the corolla) are usually of brilliant colour, and give beauty to the flower. If we remove these yellow petals, we shall find at the base of each (Fig. 1, *p*) a small scale or gland, which was at one time called the *nectary*, from the idea that it was the organ which secreted honey. It may here be appropriately pointed out that in nearly all plants with branched stems and reticulated (net-veined) leaves there is a curious relation in the number of their parts. In the buttercup before us we found a calyx consisting of *five* sepals, then a corolla of *five* petals; and in the section of the stem we count *five* bundles of woody tissue; in the other parts of the flower we shall find also the number *five*, or a multiple of it. *In all such growths the numbers* four *and* five, *or their multiples, predominate.*

Fig. 2.

Within the corolla are smaller organs, which, though more difficult to distinguish, are more important agents in the production of fruit or seed. These will require the use of a lens to be *minutely* examined, but can be distinguished in their general outlines by the naked eye. Indeed, at first sight, the distinction between the stamens, which are outermost, and of a deeper yellow—and the pistils, which are the innermost, and have a greenish appearance—will be obvious. In the common wallflower, the cherry blossom, and poppy, the difference of appearance between the stamens and the

pistils is more remarkable. Let the stamens be removed, and the mode of their attachment to the stem noted; the pistils, with the ovaries, or unripe fruit, will then be seen. In the natural process of growth the petals and stamens fall from the flower, and the unripe fruit goes on increasing without them (Fig. 1, *o*).

In the daisy the parts of the flower are not so distinct as in the buttercup; but the blossom is a type of a large number of plants, amongst which are the dandelion, sunflower, china-aster, and other flowers having a central disc with white or coloured rays around. These are called *composite* flowers, because, in fact, a great many flowers compose each blossom. It was explained that the green leaflets at the back of the flower in the daisy were not sepals, but bracts; and the pupil is therefore prepared to find calyx, corolla, stamens, and pistils within and above them. Gently pull away one of the white leaves of the flower, in such a manner as to bring away with it all the parts attached to its base. Upon careful examination it will be found that a complete floret is thus removed; and by continuing the operation, it will be manifest that the whole of the head of the blossom consists of a series of flowers crowded together upon the expanded top of the flower-stalk, which is named the *receptacle*.

CHAPTER VI.

JUNE.

"In youth from rock to rock I went,
From hill to hill in discontent
Of pleasure high and turbulent,
Most pleased when most uneasy:
But now my own delights I make,
My thirst at every rill can slake,
And gladly Nature's love partake
Of thee, sweet daisy!"—WORDSWORTH.

"Trampled under foot,
The daisy lives, and strikes its little root
Into the lap of time; centuries may come
And pass away into the silent tomb,
And still the child, hid in the womb of time,
Shall smile, and pluck them when this simple rhyme
Shall be forgotten, like a churchyard stone;
Or lingering, lie unnoticed and alone,
When eighteen hundred years, our common date,
Grow many thousands in their marching state;
Ay, still the child, with pleasure in his eye,
Shall cry—'The daisy!' a familiar cry,
And run to pluck it in the selfsame state
As when Time found it in its infant date,
And like a child himself, when all was new,
Might sink with wonder, and take notice too;
* * * * *
As once in Eden, under Heaven's breath,
So now on earth, and on the lap of death,
It smiles for ever."—CLARE.

SUMMER has come, and strews buttercups and daisies as plentifully as the merry thoughts of childhood. Let us wander again into the fields, and resume our study of our dear old favourites.

We have seen that the daisy is not a single flower, but is composed of a multitude of florets grouped together upon a receptacle, or thickened end of a flower-stalk, and that it was hence named a *composite flower*.

The central flowers are termed *florets of the disc;* in them the corolla is very little developed, but the seed-producing organs are complete. On the other hand, the flowers at the circumference, which give the appearance of rays, and are hence called *florets of the ray*, are developed at the expense of the reproductive organs (stamens and pistils), both sets of which are usually absent. The corolla in the latter appears like a white strap, or ligula, and such florets are hence named *ligulate*, or strap-shaped. In the dandelion (a near relation of the daisy) it will be found that both the flowers of the ray and those of the disc are composed of ligulate flowers; that is to say, the corolla is developed (Fig. 3). The common chicory, or succory, belongs to the sub-order *Chicoraceæ*, which has this peculiarity:—*All the plants contained in it have a kind of milky juice, which, when concentrated, is found to possess narcotic properties.* Those plants of the composite order which have ligulate flowers only in the ray, and tubular ones in the disc, are called radiate flowers, or *Corymbifera* (Fig. 4). All the plants in this order, to which belong the sunflowers, daisies, chamomiles, wormwood, marigolds, asters, &c., *have the bitterness which is common to all composite plants, combined with a resinous principle of a stimulating character: few plants belonging to this order are edible.*

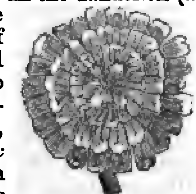


Fig. 3.

It will be observed that, by such a classification of plants as that which has been described, plants of similar characters are brought together—plants which possess similar properties as well as similar organization, appearance, &c.

Let us now note, further, the peculiarities of the buttercup, having a regard to the classification of the plant and its relations. Its parts have been cursorily described in a previous paper. When such an organization is found in a plant in which the stamens are numerous, and rise from the disc beneath the *carpels* (which are the green coverings of the seed in the centre of the flower), such plants are placed by the Natural System of Jussieu in the order of *Ranunculaceæ*, or Ranunculus tribe. All the plants agreeing in these general characters *agree also in their medical and other properties.* The juice is constantly acrid and nauseous, and in many of them is found a narcotic principle. Hence they are generally useless as food even for cattle. The Ranunculus tribe agree, moreover, in their form of growth, being either herbaceous or shrubby, never assuming the more dignified form which we call "a tree." The hellebores, whose poisonous properties are notorious, and the "deadly aconite," belong to this order.

Fig. 4.

From this it will be seen that the Natural System founds its classification, not upon any single organ or class of organs, but upon the minute anatomy and physiological peculiarities of the whole growth; and that structure is so closely allied with quality, that the same medicinal or edible properties are found more or less in all the plants grouped together.

The system of Linnæus, known as the Artificial or Sexual System, is founded on what are called the sexes in plants—that is, on the number,

situation, and relation of the stamens and pistils. The number or position of the stamens points out the class, while the orders are founded upon that of the pistils. It is, therefore, extremely easy to discover the Linnæan class and order of any flower whose parts are sufficiently large to be seen with the unassisted eye; but a series of difficulties then meet the student, who finds that he has to observe a number of other peculiarities of form, &c., before he can learn the name of the particular plant under examination. When, however, he has learned the *name* of the plant, the young botanist has learned little or nothing more, for in the Sexual System plants totally different in structure and properties are brought together; nor could he predict of any other plant which he had never before seen what would be its probable qualities and habits. Moreover, the Sexual System is uncertain, as the number of stamens, from accidental circumstances, differs in the same genus, and occasionally even in different blossoms on the same plant. It is evident, therefore, that if we desire to study the beauties of the vegetable kingdom systematically, we shall do so with more advantage by adopting the system of Jussieu than that of Linnæus. To quote the words of an eminent botanist,* "the system of classification invented by Linnæus was altogether worthy of the reputation of that great man, considering the state of science at the time when he lived; and that it effected much temporary good may, perhaps, be conceded; but the Linnæan system is superficial to the greatest possible degree; it has a manifest tendency to render those who employ it superficial also; it leads to a mere knowledge of names instead of things; and it does not lead to the application of botany to any one useful purpose."

If, on the one hand, the Linnæan system *appears* an easy and simple mode of studying the floral beauties of creation, it fails to afford the pleasure which is derivable from that intimate knowledge of every plant which is the result of a practical acquaintance with the Natural System, which

"Makes a friend of every flower we see,
The humble shrub, or graceful bending tree."

CHAPTER VII.

JULY.

"Bring a grey cloud from the east
Where the lark is singing,
Something of the song at least
Unlost in the bringing;
That shall be a morning chair,
Poet dream may sit in,
When it leans out on the air,
Unrhymèd and unwritten."—BARRETT.

"WHEN Châteaubriand returned from those tropical regions where the deep blue of the heavens presented a continual sameness, he rejoiced to see again the clouds of his native skies, serenely beautiful, and soothing the mind of him who gazes upwards with thoughts of peace."

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* John Lindley.

Thus spake an aged man to his young companions, as they went up a rocky path to the summit of Malvern.

The way was somewhat toilsome, but when they reached the highest point a glorious panoramic view of hill and dale, of woods and fields, burst upon the view; yet not less varied were the heavens in their diversity of clouds than the beauteous and sunny landscape that lay spread beneath them.

"Here, then," said the old man, "we will rest awhile, and take note concerning the beauty of the clouds; for surely it is well to become acquainted with the nature of those aqueous vapours, and the sources from which they originate, that our understandings may be enlarged, and that we may intelligently praise that gracious Being from whom all loveliness emanates—who is the source and well-spring of whatever tends to elevate the mind of man, or minister to his intellectual pleasures."

Vapours arise from off the earth; yet not from marshy places only, but from ploughed fields and plains. A slight degree of cold imparts to those exhalations a visibility which enables us to distinguish them when, assuming the character of clouds, they float across the heavens, drifted by the winds at different elevations, with every variety of form, and considerable difference of colour. The Arabs gracefully denominate them "water-urns of the firmament;" and when they have silently performed their assigned ministry, either with gentle showers or heavy rain, they as silently pass away. From them our fruitful seasons are derived; they refresh the earth, and cause it to spring forth and bud, that it may give seed to the sower, and bread to the eater. Who does not remember the delight with which raindrops—heralds of coming showers—are hailed in hot weather, when the flowers hang their heads upon the ground, and the parched earth is cracked by long continuance of drought? or when, as sang the poet, we listen to the rain at night?

> "The mighty rain is falling, at this still and solemn hour,
> Silent and yet sounding with its own unearthly power;
> Its power to call forth green leaves from the parch'd and wither'd bough,
> Bright flowers from the burnt earth, where all is barren now.
>
> "Oh! the earth was parchèd sorely when I lookèd forth at eve,
> In the hot and dewless twilight, for no cooling wind did breathe,
> And scarce the weary bird might chant his vesper song,
> And the scant rill was faintly heard as it pass'd the meads along.
>
> "But the rain is falling now with a deep and solemn sound—
> Clear streams are bursting forth in the dry and parchèd ground:
> Hark to their gentle murmur in this lone and silent hour,
> When men are stilly sleeping, and the mighty rain hath power!"

A distant shower has just fallen, and very beautiful is the effect which it produces. Yon village, with its old grey church and rookery, is obscured by the passing over of a majestic cloud, from which rain is descending like a torrent. Now the cloud begins to melt away, its blackness gradually disappears, and the sun again shines forth, lighting up the dripping landscape with a vivid radiance, and causing even the smallest wayside weed to sparkle in his beams.

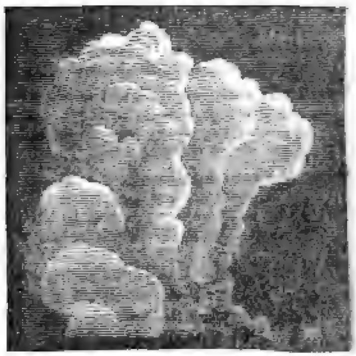
The dark cloud which seemed to disappear has, however, taken a different character, and becomes a Cumulus, or Pile-cloud—the painter's cloud, of which the exquisite modifications are now before us, heightening the beauty of the heavens, and reflecting a silvery light. Observe its peculiarity of form, its

fleecy, irregular, and fantastic outline; no two clouds belonging to this division are alike, and yet they cannot be mistaken; they often resemble rocks piled on rocks, and many an accurate observer of Nature has been surprised when, journeying for the first time through a comparatively level country,

PILE CLOUD.

he has seemed to see a line of hills stretching across the horizon, with woods, and glades, and broad rivers flowing majestically amid Alpine solitudes, till lost in the far distance. Often, too, in the calmness of a summer evening, what glorious landscapes appear to verge on the horizon, presenting the aspect of inland lakes in all their loveliness and repose, and mountains that reflect the hues of the setting sun; while here and there some opening among the hills reveals a brighter and more radiant scene, fit for angel's feet to tread—for assuredly its brightness is such as earth owns not.

A very peculiar and exquisite modification of the Cumulus rises before my mental view at the present moment. It was such as I never before witnessed, though an ardent admirer of cloud scenery from my childhood, and was such as required a combination of circumstances in order to produce a full effect. Summer had just commenced, the heavens were cloudless towards the zenith, the sun was high without any declination of his beams, and not the slightest vapour was perceptible. It was delightful to be in the open air; and having left the house to admire the profusion of roses which the garden presented, I saw, full in front, a magnificent range of ice-like mountains, sharp and angular, and of the most dazzling whiteness, apparently about half a mile distant, and lifting their conic peaks in striking contrast to the azure of the sky. The illusion was perfect, and the effect was considerably heightened by a sweep of noble trees and bushes on the right, and in the middle distance, above which the



TWAIN-CLOUD.

snow-clad peaks of the seeming ice mountains were conspicuous. Thus they continued during a full half-hour, after which they might be seen journeying along the horizon westward, kindling towards evening in the rays of the setting sun, and presenting an unspeakably glorious assemblage of every form and hue.

Such are the effects produced by the Sonder-heap, or Pile-cloud, for these are the different names which persons who delight in noting aërial scenery give to this beautiful modification.

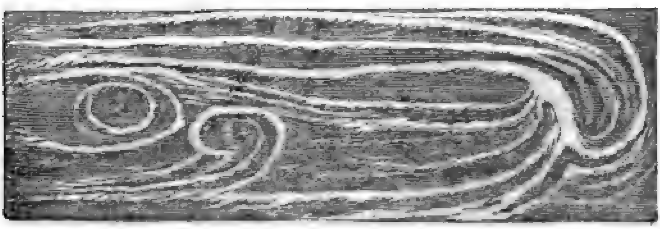
The nearest resemblance to the Pile-cloud is presented by the Cumulo-stratus, or Twain-cloud. This cloud differs somewhat from the one already described, and is rarely productive of those strange fantasies, such as Shakespeare took notice of in his day:—

> "Sometime we see a cloud that's dragonish,
> A vapour sometime, like a bear or lion."

The Twain is now visible on the horizon, over yonder range of hills. The base, if such it may be termed, of that which is in itself baseless, is mostly level, while the superstructure either overhangs the base in fleecy protuberances, or else assumes a mountainous character, resembling in this respect the conformation of the Heap-cloud, and yet differing from it in superior altitude. Two elevations of equal or slightly different heights frequently appear as if united by a drawbridge, over which the steps of celestial messengers, descending towards the earth on errands of mercy, might be thought to pass. And again, two mountainous clouds seem to rise majestically from a single base. Long ranges also often rest upon the hills, and, when thus stationary, they generally indicate a change of weather, and as frequently recall to mind the beautiful embodyings of the poet:—

> "Pleasures there are,
> That float across the mind like summer clouds
> Over a lake at eve. Their fleeting hues
> The traveller cannot trace with memory's eyes,
> But he remembers well how fair they were,
> How very lovely."—HURDIS.

High in heaven, and nearly at the zenith, appears a modification of that elegantly curling and flexuous vapour which is called the Curl-cloud, and



CIRRUS, OR CURL-CLOUD.

which generally occupies the upper region of the atmosphere, where it resembles innumerable banners floating upon a light blue sky. The Curl-cloud, varying according to the state of the air, indicates rain when, after

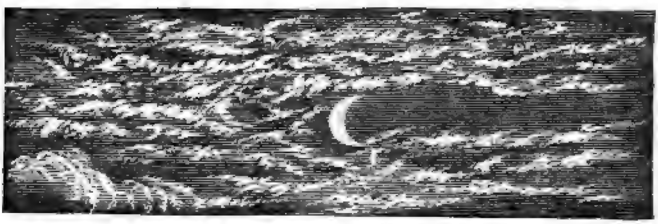
a long continuance of fine weather, it becomes a fine white fleecy lin stretched at a great elevation across the sky. It portends a gale of win when, floating at its usual lofty elevation, its curling and feathery train are directed to the same quarter of the heavens for some days, as if denotin the point from which to expect the coming gale. In warm and variabl weather, when light breezes sport among the clouds, that same flexuou vapour, ramifying athwart the blue expanse in long and obliquely descend ing bands, often unites distant masses of clouds, and presents an extremel beautiful combination of aërial imagery—most welcome, too, for the Curl cloud often predicts soft showers, as already mentioned; and thus in senti ment, if not exactly in words, has the talented historian of British bird spoken concerning it:—

"But on some day, before there is a cloud in which Hope can place he bow and limn its hues, the white flag of Mercy is hung out in the highe heaven, floating with easy folds from the south-west, indicative of victory over the desolating east; and as the day declines, little clouds flit joyously on ready wings, as if fetching the pitchers of heaven from the four corners of the sky, to refresh the weary earth and make glad all thirsty creatures. Truly the earth rejoices; echoes that haunt the wood-side soften and mellow the tumultuous sound of joy that is heard from sealed springs when leaping from out their prisons; nay, the whole creation is attuned to harmony, even as an instrument of music by a skilful hand; the groves are in song, and that not only by day, but night, for the nightingales and blackcaps, wood-larks and willow wrens, vie with one another in producing the sweetest melody; and when morning dawns, other of Nature's choristers carry on the strain, ceasing not though thunders are abroad, and heavy rain-drops patter on the leaves of trees; or if they cease for a brief space of time, when red lightning flashes through the woods, they presently commence again, and sing blithely all the livelong day."

Another and most elegant modification is the Cirro-cumulus, or Sonder-cloud, consisting of innumerable small and well-defined orbicular clouds, lying separate from one another, and yet near. Bloomfield speaks of such, in his "Farmer's Boy, as a

"Beauteous semblance of a flock at rest."

And when the moon passes in her fulness among them, silvering each small cloud, and causing it to stand forth as if in mild relief, the effect is inde-



SONDER-CLOUD.

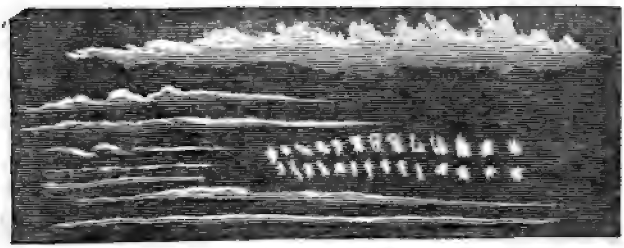
scribably lovely. In summer, the Sonder, or Separate cloud, generally indi-cates increasing heat, attended by mild rain and a south wind; but

ıter it commonly precedes the breaking up of hard frost, succeeded by ;gy and wet weather.

Few combinations are more pleasing to the eye; and thus elegantly are › thoughts which they often suggest embodied by a modern poet:—

"Unclouded was the deep serene
Of heaven's dark azure, save where seen
Around the moon soft fleeces roll'd,
Bright with the livery of their queen—
The snowy flocks of Cynthia's fold.
One might believe on such a night
Good angels choose that silvery car,
To watch, with looks of heavenly light,
Their mortal charge on Earth's pale star."

Frequently unwelcome is the Cirro-stratus, or Wane-cloud, warning of n or snow, according to the season of the year. This cloud is distin- ished by its flatness, and great extension in proportion to its height. It is



WANE-CLOUD.

n either in wavy bars or streaks, or small rows of little curved clouds, ıt uniformly precede storms; but whether stretched athwart the heavens extended and vane-like forms, or concentrated as wavy bars and wedge- ıped streaks, their appearance indicates ungenial weather. Our country ›ple, who know nothing concerning the systems of Howard, Toster, or esnel, are yet well acquainted with the changing forms of this warning ud. "It will be wet to-morrow," they often say when, looking towards › heavens, they observe the Wane-cloud on the horizon; and you seldom never find that they are mistaken.

"Wet weather seldom hurts the most unwise,
So plain the signs—such profits are the skies."—VIRGIL.

Those peculiar refractions of the solar and lunar rays, called halos, or ck suns, usually appear in this kind of cloud.

"Look! when the moon appears, if then she shrouds
Her silver crescent in long waning clouds,
She bodes a tempest in the raging main,
And brews for fields impetuous clouds of rain."

In the morning, also, if a Wane-cloud is above or across the sun, there is uniformly rain before the evening.

> "For if he rise unwilling to his race,
> Clouds on his brow, and lines across his face;
> Or if through mists he shoots his sullen beams,
> Frugal of light, in loose and struggling streams,
> Suspect a drizzling day, with southern rain,
> Hurtful to fruits and flocks, and promised grain."—VIRGIL.

There is likewise another cloud, of which the ministry is rather beneficial to the earth than serving to heighten the beauty of the heavens. This is the Nimbus, or Rain-cloud, which is more frequently a deepening of shade in the Twain-cloud, occasioned by its increasing density, than a new modification depending upon a separate change of form. The Curl and Pile-cloud may increase so much as to obscure the sky, and yet pass away without melting into rain; but when the Twain-cloud, losing its mountainous appearance, concentrates, and assumes a sullen aspect that yields to grey obscurity, it becomes evident that a fresh arrangement has taken place in the aqueous particles: the Nimbus, or Rain-cloud, is then formed, and rain begins to fall. Silently and yet sounding descends the solemn rain, refreshing the parched earth, and causing the seeds to germinate; the heavens are covered with clouds, and the sun no longer shines forth; but as in life the most gloomy moments pass away, and are succeeded by such as render the heart glad, so those water-urns of the firmament pour forth their contents, and become extinct, leaving the firmament unveiled in its clearness, or else varied with light fleecy-looking clouds.

In tropical regions Storm-clouds are singularly diversified; but, whenever seen, they possess a peculiarity of character by which they are too surely identified in those widely extended and apparently interminable plains which pertain to the interior of Africa. A single cloud is frequently the precursor of tremendous storms; such, also, is the case on the Asiatic steppes and deserts; and those of America, which, like the ocean they resemble, fill the mind with feelings of infinity and thoughts of the deepest interest. In each of those wild and desolate wastes, where no ruin recalls the memory of earlier inhabitants, no carved stone nor fruit-tree, once the care of a forgotten husbandman, but now wild, speaks of the art or industry of former generations. Those solitary clouds, uprising from the margin of the plain, and taking their place on high, are preceded and accompanied by indications that cannot be mistaken. Humboldt relates that when, after a long season of almost intolerable drought, the rainy season or some tornado is at hand, the deep blue of the hitherto cloudless sky that overcanopies the vast prairies of South America gradually becomes lighter; at night the dark space in the constellation of the Southern Cross is hardly distinguishable; the soft phosphorescent light of the Magellanic clouds fades away; and some of the largest stars alone shine with a trembling and less vivid light. Then comes the warning cloud, at first appearing small as a man's hand, or else rising like a mimic mountain perpendicularly from the horizon; vapours succeed, and spread over the sky, and loud thunders roll through the immensity of space; down comes a torrent of sonorous rain, and presently the previously barren waste begins to exhale sweet odours, and innumerable grasses speedily spring from out the earth. Sensitive plants unfold their leaves, and water-plants hold their mimic cups to catch the

streaming shower; where all before was silent, the songs of innumerable birds carol forth their praises, and vast herds of cattle, with flocks of sheep, and troops of wild horses, graze, in the full enjoyment of life, amid the tall springing grass and bushes, which seem as if they previously had no existence.

Such was the cloud which Elijah saw from the summit of Mount Carmel —that little cloud which arose from out the sea, apparently of no importance, but surely indicating the approach of a heavy storm. And so it was; "for while the prophet gave directions to his servant, the heavens became black with clouds, and there was a great rain."*

Voyagers relate that off the coast of Africa depressing heat and apparent stagnation in the atmosphere often precede a tumultuous assemblage of clouds, which gradually, and as if by unanimous consent, hurry towards the east, where they remain stationary, and form a long low arch, extending over about six points of the compass. In proportion as the lower edge of the arch becomes defined, and increases in intensity of darkness, so may the rising of a tornado be expected. When the arch is completed, a sudden squall of wind bursts forth, and woe to the vessel that is exposed to its fury, if every timely precaution has not been taken to insure her safety! Again all is still, as if sea and sky awaited some overwhelming catastrophe; but this is of short duration. The unnatural stillness is broken by a solemn preparatory note of distant thunder, accompanied by fitful flashes of lightning; to this succeed loud rattling peals. Imprisoned winds seem to rush through the low dark portals of that awful arch; their approach levels all distinctions among the waves, which are lashed into foam, and produce a bewildering mist that renders every object indistinct. Meanwhile, rains descend like torrents, and the hurricane is at its height.

Clouds, therefore, are messengers to man. They forewarn the husbandman and the sailor of coming storms, or denote pleasant weather, and awaken thoughts of gladness and serenity. Luther, looking out from his solitary castle in the middle of the night, thus religiously spoke concerning them:—"Long flights of clouds sail throughout the great vault of immensity—they are voiceless, huge, and take all forms. Who supports them? None ever saw the pillars of heaven, yet both the heavens and their unnumbered clouds are upheld. God bears them up. We know that He is great, that He is good, and we learn to trust where we cannot see."

"Ye clouds, fantastically now
Gracing the early morning's brow,
As if an artist's hand,
With the imaginings that fill'd his mind,
Had painted with the pencil of the wind
Your spirit-moving band;

"Now changed by fancy's fitful wing
Into so dark and stern a thing,
It needs must weep away,
Ere the bright smile it once had worn,
While dancing on the breath of morn,
Returns to gild its way;

* 1 Kings xviii. 44.

"Now driven by an unseen host,
From cloud-land's dark and stormy coast,
Into a feathery spray,
Robed in a snowy garb of light;
Or, rolling on in power and might,
To crown the close of day;

"'Tis e'en your battlements sublime
That Beauty calls her evening shrine;
Or, standing empress there,
Waves high her standard's perfect form,
Till all the warriors of the storm
Are mingled in the air.

"Now Nature's swiftly-rolling car
As, travelling from star to star,
She holds her silent reign;
Or in a dark and living tomb,
Surrounding in its murky gloom
The sailor on the main.

"Like thoughts of the departing soul,
Ye hang upon the brilliant goal
Of the declining day;
And lending glory its depth,
While yielding its departing breath,
Ye melt in light away."

CHAPTER VIII.

AUGUST.

THE changes of the seasons, and the varieties of temperature, have been explained. The manner in which these act upon vegetation to produce the various tints of the autumnal months must be reserved for a future chapter, to enable us to notice, in its proper order, the sequel to the chapter on Clouds. Associated with the remembrance of their fantastic beauty is the majestic grandeur of the Thunder-storm. Those exquisite vapour wreaths, that look sometimes like snowy garlands to decorate the blue triumphal arch of heaven, at other times assume a darker hue, and remind us of the contests of the angels, which the sublimest poet has described; for those mountainous heaps of vapour grow into dark rolling masses, such as might be imagined to result from the "artillery of heaven;" and often, too, from out their murky bosom, flashes a streak of forked fire, dazzling, and sometimes even destroying, the sense of sight with its brightness; and then the ponderous thunder—whose sound has been compared to "the rolling of the chariot wheels of God o'er the blue floor of heaven"—comes, with its astounding vibration, shaking the solid earth, and startling all creation with fear.

It has already been explained that clouds are composed of water in a vesicular condition. Each of the vesicles is charged with electricity, which it has derived during the process of evaporation, and which is the probable cause that this peculiar state of water which is discovered in the clouds has any degree of permanence. The repulsion produced by the vesicles being *charged* with the *same* kind of electricity is believed to be sufficient to *prevent* coalescence between the bladders of water and the formation of rain.

"It is probable, moreover," says Professor Thompson, "that when two currents of air are moving different ways, the friction of the two surfaces may evolve electricity; should these two currents be of different temperatures, a portion of the vapour which they always contain will be deposited; and the electricity evolved will be taken up by that vapour, and will cause it to assume a vesicular state constituting a cloud." Some clouds are charged with vitreous, others with resinous electricity—that is to say, that they may be either positive or negative; and when two masses of vapour thus oppositely charged approach each other, a flash of lightning passes from one to the other; and the discharge, accompanied by a tremendous report, dissipates the electricity which was necessary to the maintenance of the vescuilar condition of the vapour, and rain-drops are immediately formed. Hence heavy rain invariably accompanies a thunder-storm, at the same time that it diminishes its dangers. The discharges of electricity usually take place between different strata of air in different electric conditions, or between clouds. Rarely a cloud charged with one kind of electricity nears the earth, which is in an opposite condition, and then the flash is from the earth to the cloud, or more commonly from the cloud to the earth. In the latter case a "thunder-bolt" is said to fall.

When, however, an electric spark passes from the atmosphere to the earth, no material or substance can be discovered; and the descriptions which have been published of so-called "thunder-bolts" are, for the most part, fabulous. At the same time it is to be admitted that meteoric stones have fallen from the sky, accompanied with a loud noise *like* thunder; but these are of an entirely different nature from a discharge of electricity, and are called *aërolites*, or *wandering stars*. It will be sufficient here to say that they are composed of iron in a high state of purity, presenting marks of recent fusion, and have been supposed to be portions of some shattered planet, whose parts are still revolving round the sun in eccentric orbits, approaching that of the earth at set periods so nearly, that the attraction of our mass is sufficient to drag them from their courses, and to draw them to the surface of our planet.

The devastation and marks of violence produced by a discharge of electricity from the clouds to the earth suggested to our ancestors the idea of the action of some solid body sent with violence against the objects it shattered; but with the progress of science men have learned that the agent which can shatter a tower, demolish a spire, fire a powder magazine, split rocks, rend trees, and instantaneously destroy life, with scarcely a mark to show a trace of its operation, is an imponderable agent—that is, a thing without weight or substance, only manifesting effects—like heat. This is called electricity, because it was found that phenomena of a similar character can be produced upon a small scale by rubbing amber (called *electron* by the Greeks), or vitreous or resinous substances. This relation between what was called electricity and the nature of lightning was discovered only in recent times by Benjamin Franklin, the son of a tallow-chandler, and a printer's apprentice, afterwards Doctor of Laws, Fellow of the Royal Society, and Minister Plenipotentiary from the United States of America. The discovery of oxygen was owing to the use of a simple bird fountain; and the identity between lightning and electricity was proved by a schoolboy's toy—a kite. Hence let us learn, *en passant*, that no station, however humble, has no opportunities of adding to human knowledge; and that no instruments,

however insignificant, are to be thought useless in our examination of the beautiful world around us.

Before Franklin suggested his remarkable experiment, it had been demonstrated that electricity is attracted by points, and, if highly excited, that it discharges itself with a flash and report. Moreover, the atmosphere was known to be susceptible of electrical influences; and it was urged by the philosopher that the analogies which existed, pointed, at the least, to a probability that lightning was a discharge of electricity. With a view to settle the question, he made the following experiment:—A kite was made with a pointed wire fixed to the stick which formed its centre, and this was elevated in the air during a thunder-storm; as the string became wetted, and so formed into a conductor of electricity, vivid sparks and sharp reports passed from the lower end of it, and no longer was there any doubt but that lightning and electricity were identical.

The noise which we call "thunder" is usually heard after a discharge of electric fluid from the clouds, but *not always.* If the clouds approach bodies having a great number of points, or are themselves more or less fringed, a broad flash, consisting of innumerable small sparks, may be seen, and no noise will follow. To perform the experiment upon a small scale, the student may present to an electrical machine, from which large sparks would fly to the knuckle, a bunch of pointed instruments, such as darning-needles; he will find that to these needles the electricity will stream off almost in silence. If the experiment is conducted in the dark, the effect will be very evident. Generally, nevertheless, thunder accompanies an electric discharge from the clouds. The character of the sound is variable: it sometimes resembles that which we hear when a single cannon is fired; at other times it is a rolling noise, like that produced by several great guns fired quickly one after another; and sometimes, again, it has a sharp cracking sound, like the reports of a number of rifles fired in rapid succession. The physical cause of the detonation is not well understood; it is probable, however, that the lightning, owing to the difficulty with which it passes through the air—which is a bad conductor—raises the temperature of that medium to an extreme, and produces a sudden expansion, which is followed by as rapid a condensation. Moreover, an alteration of the composition of the air takes place to a slight extent, nitric and nitrous acids being produced by a union of the oxygen with the nitrogen of the air, in consequence of which further condensation takes place. From these causes arises so violent a disturbance of the air that violent vibrations follow, constituting the sound of thunder. Various reasons have been assigned for the prolongation of the sound, but none of them appear to be quite satisfactory alone; probably all of the causes which have been mentioned combine to produce the lengthening out of the report. It was formerly supposed that the rolling noise was merely a succession of echoes, or of reflected sounds falling upon the ear in a succession, according as the objects reflecting the undulations were near or distant. Clouds, mountains, forests, buildings, or rocks were the reflecting agents in this supposition, which was founded upon the fact that the noise of fire-arms discharged in a mountainous district is prolonged by echoes during at least half a minute, or about the time during which the rolling of thunder continues. But it is singular that the prolongation of the sound is not always heard, as it should be if this theory afforded a complete explanation of its cause; on the contrary, we find the

when the heavens are uniformly covered with clouds, a flash of lightning will dart from the zenith, and a crash of thunder follow it, *without* prolongation: within a few minutes of the first discharge a second discharge may occur in the same part of the sky, and yet be accompanied by the rolling prolongation. From this it would appear that there must have been something different in the character of the two discharges, and that the "roll" was *not* entirely due to echoes. These peculiarities may, perhaps, be explained by remembering how the different sounds produced by the explosion of gunpowder, to which the various kinds of thunder have been compared, are created: for example, as the firing of a single great gun produces a quick booming sound, so the short crashing kind of thunder without prolongation may arise from a great but a single electric discharge; as the firing of several great guns in succession produces a rolling sound, the prolonged roll of thunder may, perhaps, arise from a number of electrical discharges either following each other, or taking place at once at *different distances from the ear*. Now, it has been observed by Dr. Hooke that "the flashes of lightning are simple or multiple: the former occupy only but one small portion of space, and give rise to an instantaneous report; the multiple flash takes place at different parts of one long line," and a number of reports come in the order of distance to the observer.

The flash of lightning and the report take place at the same moment; but since sound travels at the rate of rather more than eleven hundred feet in a second, while for short distances the passage of *light* may be considered instantaneous, it follows that on counting the number of seconds between the flash and the report, the distance of the thunder-cloud may be ascertained in feet by multiplying 1,100 by the seconds counted. Thus, if five seconds elapse between the flash of the lightning and the first sound of the thunder, the distance of that discharge would be $1,100 \times 5 = 5,500$ feet, or about a mile.

An opinion exists that thunder has been heard when the sky was without a cloud; but the fact cannot be said to rest upon good authority. In some cases the subterranean sounds which precede earthquakes have been mistaken for thunder. It is, however, worthy of remark, that death has occurred from the passage of electricity from the earth to strata of air, when thunder-clouds were at a great distance.

Thunder and lightning are believed not to occur in the Arctic or Antarctic regions beyond the seventy-fifth degree of north or south latitude; and even as low as the seventieth degree these phenomena are very rare.

Though the noise of thunder is very awful, it cannot be considered dangerous. The real danger is from the lightning, which has a tendency to fly off from the overcharged clouds towards the earth, from which the electricity has passed during the evaporation of water. The nearer the cloud to the earth, the more likely is a discharge to take place; and hence the tops of mountains, or of high buildings, are most frequently the points of attraction and discharge. Where the electric discharge has the opportunity of passing to the earth without opposition, or along a conductor of electricity (such as a metallic bar), it does not do any mischief; on the contrary, where the object through which it seeks a passage to the ground is an imperfect conductor, it is always more or less shattered. The reverse is also true; for if the electric fluid seek a passage from the earth to the clouds through the substance of a high building composed of badly conduct-

ing materials, equal mischief will result. To obviate these dangers it is usual to attach a metal rod to the side of valuable or high buildings, in such a manner that its upper end shall extend to some distance above the highest part of the erection, while the lower end is carried down into the earth for a considerable distance. Experience has proved that pointed rods, contrived thus to facilitate the passage of the lightning to the earth, protect the buildings with which they are connected, by producing a gradual discharge from the thunder-clouds passing over them. They should extend from twelve to thirty feet above an ordinary house, and should be carefully constructed, to secure an uninterrupted passage of the electric fluid to the earth. To prevent the points becoming blunt by rust, they should be made of copper covered with gilding, or of platinum; and to prevent the rod from being fused by the heat of a large current, it should be made of such a thickness as to allow a large stream of the fluid to pass.

CHAPTER IX.

SEPTEMBER.

THE name September is no longer appropriate to this, the ***ninth*** month of the year, as it is now divided by European nations, since the term is derived from the Latin *septem* (seven), and the termination *ber*. The same inappropriateness may also be urged against Octo-ber, Novem-ber, and Decem-ber, which titles severally mean the eighth, ninth, and tenth months. The Roman year originally commenced in March, and the names of all the months were Latin terms; hence the old lawyers, who wrote in Latin, supposed that the year commenced as in the Roman calendar, which would make September the seventh month. Indeed, the "legal year" was not made to commence on the 1st of January till the act of parliament was passed for the alteration of the style of chronology in 1752.

The wheat harvest has been begun and is nearly finished before the month has half run its course; and from field and wayside, wood and hilly slope, there steams up a fragrance like the incense offered by the grateful earth to heaven. But the warning tints of autumn are coming on. "The bright-leaved walnut, the rough-foliaged mulberry, the fingered horse-chestnut, are nearly bare; and the leaves that flutter on the delicately-clothed lime and the broad-handed sycamore are few. The maple, the ash, and the hornbeam assume a yellow pall; while the cherry and the dogwood tree are dressed in glowing red. The plane-tree, with its angled leaves, and the hawthorn, with its scissored foliage, are tawny in their autumn dress; while the stalwart elm is orange in its mourning. Nuts hang upon the boughs for gathering, and berries crowd upon the privet and blackberry; but the nightingale has gone from the woods, and the swallow has left the solemn avenues in their stillness. In their room the death's-head moth flaps its broad slow wings over the grave of the summer time; while the 'shard-borne beetle' trumpets a low requiem in the chilly air."

In a former article some information was given about the electrical discharges which take place from the clouds. When rain occurs, accompanied by thunder and lightning, the phenomenon is called a "thunder-storm," or

more commonly "a storm." But this term is variously applied in different countries. In some instances a violent agitation of the atmosphere is called a storm of wind; and we have, moreover, "hail-storms," "snow-storms," "sand-storms," &c.

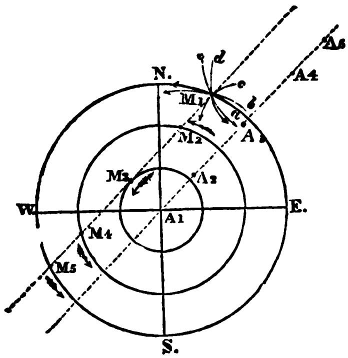
It has been explained that there are storms of regular occurrence in many countries situated in the torrid zone, called monsoons, simooms, tornadoes, &c. Of these it is unnecessary to speak further, but more especially to notice the phenomena of wind-storms or hurricanes, which occur with much irregularity in various warm climates, and whose effects, diminished in intensity, we not unfrequently feel in northern latitudes in March, and towards the latter part of September. This will form an appropriate sequel to the previous article on "thunder-storms," or storms accompanied by electrical discharges.

The "law of storms" has been the object of great attention during the last few years; or, in other words, great efforts have been made to discover the circumstances under which wind-storms, or hurricanes, arise, and to obtain observations of the phenomena which they present. At first sight their action and occurrence *appeared* irregular, and we might almost say capricious; but the laws of the universe were ordained from the beginning, and nothing can be accidental. The phenomena which *seem* the most irregular are often found to be, in fact, the very reverse; and "exceptions," over and over again, "have proved the law." As an example of this we might note how the aberrations of the planets at first appeared to disprove the Newtonian theory, but were, upon examination, found to show that gravitation was a universal principle, and that the views of Newton were beautifully confirmed by that which was adduced as an exception. For a long period the law of storms assumed no very definite form, the question of chief difference being whether wind-storms or hurricanes were direct currents or great whirlwinds. It is, however, now generally admitted that, though there may be currents of air passing over portions of the earth's surface with great rapidity, such wind-storms rarely or never do much mischief, or assume such violent characters as those wind-storms which are of a circular form, or whirlwinds. "The general phenomena of these storms will be understood if the storm, as a great whirlwind, be represented by a circle whose centre is made to progress along a curve, the circles expanding as they advance from the point at which the storm begins to be felt—the rotatory motion, in the northern hemisphere, being in the contrary direction to that in which the hands of a watch go round."* In the southern hemisphere the rotatory motion is in the opposite direction.

It appears that the East India fleet and other vessels, in 1809, experienced a dreadful storm in latitudes near the Cape of Good Hope. "Some of the vessels scudded and ran in the storm for days; some, by lying-to, got almost immediately out of it; while others, by taking a wrong direction, went into the heart of it, foundered, and were never heard of more; others, by sailing right across the calm space (in the centre of the whirlwind), met the storm in different parts of its progress, and the wind blowing in opposite directions, and considered and spoke of it as two storms which they had encountered; while others, cruising about within the bend of the curve,

* Lieut.-Col. Reid's Paper read to the British Association, 1838.

but beyond the circle of the great whirl, escaped the storm altogether."* To explain this more clearly, let us request the reader's attention to the diagram. Let the plane surface of the paper represent the surface of the sea, and a line through A 1, perpendicular to it, represent the axis of a whirlwind, whose north and south diameter is represented by the line N S. To realize this idea, place the point of a pencil on the point A 1; when the pencil is held in a vertical position it represents the axis of the storm's motion. The particles of the air are supposed to revolve in the direction indicated by the order of the letters N W S E; the axis is, moreover, supposed to have a progressive motion from A 1 through N. Now, it will appear that since at N a tangent to the circle lies due east and west, a ship at that point would experience a wind blowing from the east when the centre of the storm is at A 1; and that the wind will continue to blow from the same quarter till A 1 arrives at N; but after that period the wind will appear to blow in the opposite or westerly direction, till the remaining portion of the storm has passed over that point N. In the same manner, if the axis of the storm were supposed to move from A 1 to W, it is plain that at first a ship at the latter point would experience a north wind, and would continue to do so till the axis of the storm had passed over it, after which it would be exposed to a southerly wind in the second half of the storm. Suppose, however, that the axis of the whirlwind progressed from A 1 to A 5, and that the storm took a north-*easterly* direction instead of a course due north, and that, moreover, while the rotatory motion continued in the same direction, the ship remained stationary at some point, as M, till the storm had passed over it; then the line of direction in which the points of the whirlwind successively overtake the ship being M 1, M 2, M 3, M 4, M 5, parallel to A 1, A 5, the arcs *a* M 1, *b* M 1, &c., will indicate the several directions in which the wind will blow upon the ship during the storm. Or, to explain this in more popular terms, the storm passing in a north-easterly direction first comes to the ship at M 1, and then blows from the south-east in the direction *a* M; when the storm has passed over the ship till it occupies the position represented by M 2, the wind becomes almost due east, in the direction represented by *b* M 1; when the storm has advanced still further, and the ship assumes the relative position of M 3, the wind becomes north-east, or blows in the direction of *c* M 1; the wind would then appear to veer round gradually to due north, north-west by north, and at M 4 would blow from the north-west. In fact, to a ship at the point M 1, over which a hurricane, whose centre was successively at A 1, A 2, A 3, A 4, and A 5, the wind would blow in the different directions indicated by *a b c d* and *e*.



* Redfield's "Observations on Storms."

By a complete knowledge of the law of storms the experienced captain can so guide his vessel as to avoid the storm altogether, or to keep in its rear. The study of this subject is, therefore, essential to safety in navigation.

Many of our readers will have observed how, in calm weather, sand and dust are carried by the wind with a whirling motion through the air, and that, on the approach of a storm, larger whirlwinds carry up sand and dust into the air. But rotating *hurricanes* seldom appear beyond the tropics, though it is believed that all our violent wind-storms have a rotatory motion. The devastations occasioned by them in the hotter climates, where sudden condensations of vapour give rise to the rushing in of opposing winds, and thus originate whirlwinds, are truly frightful. Thus, for instance, in the memorable tornado which desolated Guadaloupe in 1847, solidly-built houses were torn up, and their parts thrown to considerable distances; cannons were hurled from the top of the parapets of the batteries on which they were placed; and it is related that a plank of about three feet in length, eight inches in breadth, and ten lines in thickness, was propelled by the air with such force that it perforated the stem of a palm-tree seventeen inches in diameter.

It has been observed that the progressive motion of whirlwinds is from the equator towards the poles; and by this fact the observer may ascertain his position with reference to the storm. This fact has thrown a curious light upon the question of the nature of the spots on the sun, which, it is well known, take the same direction from his equator to his poles as our earthly whirlwinds. It having been decided that the luminosity of the sun depends upon his atmosphere, there is little reason to doubt but that the spots are the centres of solar hurricanes, from which the radiant medium is thrown by the centrifugal force produced by the rotatory motion.

CHAPTER X.

OCTOBER.

> "Grey mists at morn brood o'er the earth,
> Shadowy as those on northern seas:
> The gossamer's filmy work is done,
> Like a web by moonlight fairies spun,
> And left to whiten in the breeze.
>
> "Far sails the thistle's hoary down;
> All summer flowers have pass'd away;
> This is the appointed time for seed,
> From the forest oak to the meanest weed—
> A time of gathering and decay."—MARY HOWITT.

THE summer has indeed gone. The bright tints of gay flowers have faded, and the motley garb of the woods speaks only of maturity and decay. The leaf, the flower (and shall we not add—man?), each serves a purpose in the world, and, having more or less perfectly accomplished it, departs. Solemn thoughts are suggested by the accession of autumn—the falling of the leaf, the mist-hung scenery, and fading vegetation; for there is enough of the poetic temperament in the majority to apply the analogy to human

life, "which groweth up like the grass, and to-morrow is cut down and withered."

The swallows, like the flighty ambitions of our youth, or like false friends, have departed. For days before they leave us they may be seen assembling on church towers, elevated buildings, or willow plantations by the river sides. At first a few only perch, and, like touters for steam-packets, loudly scream that the company will start from that particular locality. Presently, high wheeling above our heads, we may see a thousand of their fellows, apparently in a high degree of excitement, screaming to each other as if they were determined to enjoy a good frolic before finally leaving the pleasant scene, and entering upon their long and dangerous journey. Gradually, towards sunset, we have seen them come down like a shower of birds, and blacken the point of rendezvous, where they rest till early morning, where we look for them in vain. Indeed, there appears something magical about their disappearance; for upon several occasions having observed their assemblage at nightfall, we have risen with the grey light of morning to see the host depart, but the travellers have always been up before the sun, and out of sight before we reached their rendezvous.

It has been remarked "that no living creatures which enliven our landscape by their presence excite a stranger sympathy in the lovers of Nature than migratory birds. They interest the imagination by that peculiar instinct which is to them chart and compass, directing their flight over continents and oceans to that one small spot in the great world which Nature has prepared for their reception—which is pilot and captain, warning them away, calling them back, and conducting them in safety on their passage; that degree of mystery which yet hangs over their motions, notwithstanding the anxious perseverance with which naturalists have investigated the subject, and all the lively and beautiful associations of their cries and forms, and habits and resorts. When we think for a moment that the swallows, martins, and swifts which sport in our summer skies, and become cohabitants of our houses, will presently be dwelling in the heart of regions which we long in vain to know, and whither our travellers toil in vain to penetrate; that they will, anon, fix their nest to the Chinese pagoda, the Indian temple, or beneath the equator, to the palm-thatched eaves of the African hut; that the small birds which populate our summer hedges and fields will quickly spread themselves over the regions beyond the Pillars of Hercules, and the wilds of the Levant, of Greece, and Syria; that the thrush and the fieldfare, which share our winter, will pour out triumphant music in their native wastes, in the sudden summers of Scandinavia—we cannot avoid feeling how much of poetry is connected with these wanderers of the earth and the air."

The swallows are a family of birds living upon insects, and in which the powers of flight attain their highest development, while the feet are comparatively useless for the purposes of locomotion. It occupies different positions in various classifications. The European species of this family are the "true swift," the "white-bellied swift," the "rock martin," the "rufous swallow," the "martin," and the "sand martin." The true swift, the rufous swallow, the martin, and the sand martin visit Britain in the summer time; the rest rarely or never come to our shores. In the true swift the leg is thickly feathered almost to the claws, and all the four toes are directed forwards. It will be seen from this that the swift cannot perch

upon a bough or take hold of anything: its foot is in the same predicament that our hands would be if the thumb were removed. This beautiful creature comes to this country early in May, and leaves us towards the end of August. It comes the latest and departs the soonest of its tribe. It is the largest of the swallows which visit us; but its weight is exceedingly small when compared with its extent of wing—the former being scarcely an ounce, the latter nearly eighteen inches. Owing to the peculiar conformation of the feet to which we have already alluded, and which are smaller than in any other of its own species, it walks upon the ground with difficulty, and finds it almost impossible to rise, because its feet render it no assistance in springing, and its wings and tail are so long as to beat the earth, and thus become less an aid than an impediment.

We remember, a few summers ago, that a swift having been caught in its nest, was placed upon a grass-plat, and found itself quite unable to escape. It was suspected that its wings had been injured, or that some violence had been done to it in its capture; but, upon examination, no such calamity ppeared to have befallen it; indeed, while the question was being discussed, the swift took flight from the hand with perfect ease, and like an arrow darted up into its natural element, the air. It was remarkable that the nest, which was within reach of the window, was not forsaken by the bird, even though the graceful aëronaut was repeatedly caught at night in its place of roost.

The swift is more upon the wing than any other swallows, and its flight is more rapid; hence its name—"swift." As it wings its graceful course it seems to announce its joyousness by a screaming of peculiar shrillness. It rests by clinging against a wall, and breeds under the eaves of houses, in steeples, and other lofty buildings, where it constructs its nest of grasses and feathers, and lays two long white eggs. Its colour is a dark glossy black, the chin only having a white spot upon it. It was a popular superstition at one period that there was in India a bird which had no feet, lived upon celestial dew, floated perpetually on the air, and performed all its functions in that element. Referring to this, Mr. Pennant says, "The swift actually performs what has been disproved of the bird of Paradise; except the small time it takes in sleeping, and what it devotes to incubation, every other action is performed upon the wing." The materials of its nest it collects either as they are carried about by the winds, or picks them from the surface of the ground. Its food is undeniably the insects which fill the air. Its drink is taken in transient sips from the water's surface. These wonderful birds rise very early and retire to roost very late, remaining in incessant activity during the long summer days. A pair whose motions we observed some years ago were on the wing, on more than one occasion, from a little after four in the morning till nearly nine o'clock at night. Those residing in a particular neighbourhood seem to assemble like human families before bedtime, and shrilly wish each other "Good night" in the high air, and forthwith, with one accord, to come down to their nests. Great power of sight is, of course, indispensable, both to enable the bird to obtain its food and to insure its safety in its rapid flight; but this power is not always sufficient to guard it against accident. Mr. Yarrell relates that he saw a swift, "on eager wing," dash itself against a wall; it was picked up stunned, and died almost immediately in the hands of the observer. In its northward career its visits are not confined to England, but extend to the

whole of Europe. When it leaves us it goes to the northern shores of Africa and similar latitudes. It has been seen at the Cape of Good Hope, and in the island of Madeira. The qualities of the swift are thus quaintly summed up in the *Portraits d' Oyseaux*:—

> "Le Moutardier, ou bien grand Martinet,
> Est à voler tres-leger et forte viste:
> Mais sur la terre il ne pose, ny giste,
> Car y estant, sur pieds mobile n'est."

These birds, deriving their food, as they do, from matters floating in the atmosphere, are apt to catch at everything; and in the island of Zante the boys avail themselves of this circumstance to fish for swallows with a hook baited with a feather, and are related to have caught as many as five or six dozen per day.

Swifts and swallows are the inveterate persecutors of hawks; the latter are especially active in attacking such predacious intruders, and persevere as long as the opportunity remains.

In connection with this subject it will be appropriate to allude to the general structure of birds, and to point out the chief points in which they differ from other creatures. It is manifest that they must be very light, and yet, in the case of those who indulge in long flights, they must be very strong. Now it would appear that, to secure great strength, large muscles must be used; and these, to be efficient, must have strong bones to support them, as points of attachment. But the difficulty arises, how can this organization be combined with the lightness required? This, which might have puzzled any human architect, is achieved by the DESIGNER of the bird. All its bones are hollow, and can be filled with hot air each time the bird breathes; its body, also, is small in proportion to the extent of its wings. The covering of these denizens of the air presents every variety of texture and tint. How gorgeous is the metallic lustre of the peacock, the kingfisher, or the humming-bird! how rich the colours of the parrot or the flamingo!

> "In plumage delicate and beautiful,
> Thick, without burden, close as fishes' scales,
> Or loose as full-blown poppies in the breeze,
> With wings that might have had a soul within them,
> They bore their owners with so sweet enchantment."

Birds have no teeth, yet their food, in many cases, is of such a character as to demand mastication; but teeth would have been a very heavy piece of machinery. The food, when obtained, is transferred to the crop or craw, from thence to a membranous bag, where it is soaked in a kind of saliva, and then is conveyed to a third stomach, where the process of digestion is completed. In birds which feed upon grain, the sides of the stomach are of considerable thickness, and are surrounded by very powerful muscles. Here, with the aid of small stones and sand, the food is ground as in a mill, instead of being masticated by the teeth; yet comparatively few persons know that the gizzard, or stomach of the fowl, is such a curious piece of machinery. Our space here does not permit more to be said on this subject.

CHAPTER XI.

NOVEMBER.

" Hung o'er the farthest verge of heaven, the sun
Scarce spreads through ether the dejected day;
Faint are his gleams, and ineffectual shoot
His struggling rays, in horizontal lines,
Through the thick air, as clothed in cloudy storm,
Weak, wan, and broad, he skirts the southern sky;
And soon descending to the long dark night,
Wide-shading all the prostrate world, resigns.
Nor is the night unwished; while vital heat,
Light, life, and joy, the dubious day forsake.
Meanwhile, in sable cincture, shadows vast
Deep-tinged and damp, and congregated clouds,
And all the vapoury turbulence of heaven,
Involve the face of things. Thus Winter falls,
A heavy gloom, oppressive o'er the world.
* * * * * *
Then comes the Father of the tempest forth,
Wrapp'd in black glooms. First, joyless rains obscure
Drive through the mingling skies with vapour foul,
Dash on the mountain's brow, and shake the woods,
That grumbling, wave below. The unsightly plain
Lies a brown deluge, as the low-bent clouds
Pour flood on flood; yet unexhausted, still
Combine, and, deepening into night, shut up
The day's fair face."—THOMSON.

HE short dark days and the cold nights tell us that winter has come in train of the yellow autumn. Plants and annuals alike seem dull, and ay assume the aspect of death. Rattling hail or more penetrating sleet es pelting pitilessly into the face of the poor pedestrian, or hisses down chimney, where the fire, rendered necessary by the inclemency of the on, flickers before the family circle. Far away in the country, desola- seems to reign. The wind comes howling and mourning over the heath, mocks the leafless boughs of the trees together with a dismal noise. ure has changed her habit of joyful green for a robe of sombre russet, the songsters—all save the cheerful robin—are dumb.

he fogs and mists of October and November are the terrestrial pheno- which are most noticeable in our climate, and which are a kind of oach to us in the eyes of foreigners, living in latitudes where the tempe- re does not usually descend so low. The vapour of water, when com- ely taken up or dissolved in the air, is invisible; indeed, the atmosphere hardly ever be said to be without a considerable quantity of water olved in it. At any time a glass containing a freezing mixture will be d to condense upon its sides the water which has hitherto existed unseen the surrounding vapour. If you observe the cloud of steam from a motive, as it dashes on its iron way, you will perceive that the cloud at is very thick, but that it gradually fades, till at last it " vanishes thin air." The vapour of water, however, is only invisible when the

air is of as high a temperature as itself; for when the temperature of the air becomes lower than the point at which water can preserve its vaporous form, the latter becomes visible, and forms *a mist or a fog.*

Water, in the form of transparent steam or vapour, is continually rising into the atmosphere at all usual temperatures; even at, or below the freezing point, from ice and snow, evaporation goes on, for these solid substances gradually disappear without becoming liquid when the atmosphere is dry. Yet heat is the sole cause of the conversion of all liquids into vapour, and solids into liquids. Ice melts at the fireside, as also wax and tallow; the average temperature of the air is sufficiently hot to keep water in the fluid condition, but it is cold enough to freeze wax, tallow, lead, and iron.

The quantity of vapour given off by water is (other things being equal) in exact proportion, therefore, to the temperature of the atmosphere; and hence it is that the earth soon dries in summer, while the surface remains wet for a long while in winter. Just as hot water will dissolve more sugar than the same quantity of cold, so heated air will take up or absorb more water than cold air. Hence there is more water in the air in summer than in winter, and in hot than in cold climates. But some one may say, "The weather is very damp in winter." This sense of damp arises from the fact that the vapour of water is in the act of condensation, or, in other words, that mist or rain is about to be formed on account of the coldness of the air.

So completely is evaporation regulated by temperature, that we find the quantity of vapour in the air diminishes in a regular proportion from the equator to the poles. This will appear at first sight contradictory, inasmuch as it asserts that the atmosphere contains more moisture over the great African desert of Zahara than over the fens of Lincolnshire. Any expansion of the air is accompanied with a readiness to absorb water. If a shallow saucer, containing water, be placed under the receiver of an air-pump, and a part of the air removed, a considerable part of the fluid will rise under the glass, but will be quite invisible; but if the outer air be suddenly admitted, the internal air will be condensed, and the moisture which it had taken up will form a mist, and collect like dew upon the sides of the receiver. As the quantity of vapour which the air will contain at any time is limited by the *state of expansion* of the latter, and this expansion always depends upon heat under natural circumstances, we are only strengthened in our view, that the quantity of vapour of water in the air is regulated entirely by temperature. If the air be saturated with moisture, the abstraction of heat will make it contract and deposit some of the water as vapour, or cloud, or dew, or rain, in proportion as the reduction of temperature is great or little, gradual or sudden.

In so changeable a climate as ours there is a frequent tendency to destroy the transparency of the air, owing to the causes just named, and our atmosphere is rarely clear. But in early morning, soon after sunrise, *if there has been a heavy dew* (which means that the moisture of the air has been precipitated), before the sloping rays of the sun have had power to raise new vapours by evaporation, the air may often be discovered perfectly transparent even at this season of the year. On such occasions the view has a singularly beautiful appearance, owing to the sharpness of the outlines of the details of the landscape.

When the vapour has been accumulated in a great quantity in the air, and a sudden and considerable reduction of temperature takes place, a *fog* is

produced, which is, in fact, a cloud too heavy to float, and which rests upon the earth. The London fogs are proverbial; but in all large towns, especially those in which manufactures are carried on, there are similar phenomena. Their peculiarity consists in their being compounded of smoke and vapour, which gives them greater density than ordinary mists, and causes them to feel more unpleasant to breathe. At these times, if the observer walks a few miles beyond the houses, and gains the summit of a hill, he will find the sky clear and the air transparent; while in the house-crowded valley lies the fog, like an outspread garment, or a patch of snow, or a lake, with the spires and chimneys, and here and there the housetops peeping up through it above the level.

When the days become short, and the rays of the sun have very little time to warm the earth, the surface becomes very cold, and the air which is in contact with it deposits the moisture which it before contained; thus arises DEW:—

"Of bloom ethereal, the light-footed dews."

Dew is deposited, in the form of minute globules, whenever the ground is colder than the air; but upon these occasions the air does not lose its transparency. Sometimes the air contains so little moisture that although the earth becomes very cold, little or no dew is deposited. It is, moreover, rarely deposited in any considerable degree when the weather is windy or the sky is clouded. It is more plentiful in spring and autumn than in summer, probably owing to the greater difference in the temperature between the day and night in the two former, especially autumn. It is also more copious on those clear and calm nights which often occur early in November, and which are followed by misty or foggy mornings; or when a clear morning succeeds a night which was clouded in its first hours. When the clearness and stillness of the atmosphere are the same, more dew is formed between midnight and sunrise than between sunset and midnight. The cause of this is, evidently, that during the former part of the night the earth had not so completely given up its heat as it has during the hours after midnight. If, however, clouds hang in the sky, the heat which otherwise would be radiated away without any return, is reflected back again to the ground, and less dew is then to be found. This radiation of heat, and the production of cold thereby, are the subject of the following curious observations by Dr. Wells, which are not inappropriate here:—

"I had often," he says, "in the pride of half-knowledge, smiled at the means frequently employed by gardeners to protect tender plants from cold, as it appeared to me impossible that a thin mat, or any such flimsy substance, could prevent them from attaining the temperature of the atmosphere, by which alone I thought them liable to be injured. But when I had learned that bodies on the surface of the earth became, during a still and serene night, colder than the atmosphere by radiating their heat to the heavens, I perceived immediately a just reason for the practice which I had before deemed useless."

Dew forms in very different quantities under the same circumstances upon different materials—on metals sparingly, because they radiate heat imperfectly, but upon animal substances copiously, because they part with their heat more rapidly. And in conformity with the theory of radiation, it is observable, likewise, that whatever diminishes the view of the sky, as

seen from the exposed body, occasions a less deposit of dew upon *it* than upon bodies not so protected.

CHAPTER XII.

DECEMBER.

"The old tree hath an olden look;
The lonesome place is yet more dreary;
They go not now, the young and old,
Slow wandering on by wood and wold;
The air is damp, the winds are cold,
And summer paths are wet and weary."—MARY HOWITT.

BRIGHT, dazzling, frosty days, and glorious transparent nights, associated with crackling logs on the glowing hearths, are the ideas that cluster round the memories and experiences of December. Christmas holidays to the young, home reunions and merry meetings, seem almost essential to the realization of the time. It is called the *depth of winter*, and towards the latter part of the month the lowest temperature of the year is experienced. At the beginning of the month, indeed, there is sometimes mild weather, if the north or north-east winds do not prevail; and we remember in one instance recently to have seen a jasmine blossom, on a sunny aspect, as late as the 4th of this cold month.

The trees are bare, and all vegetation seems dead. When the first frosts set in, the effects of the cold upon growing vegetation are most singular. A plant which was green the day before is white with frost in the early morning which follows, and fades into a dismal black as soon as the sunbeams begin to warm the frozen branches, and melt the fringe of hoar-frost which sparkles upon the foliage which it killed while it adorned. The explanation is not difficult, for we find an analogy in the experiences of animal life. There are many animals which bear an exposure, for a considerable time, to severe cold, without suffering material injury; and these same creatures will often be able also to resist the injurious effects of an equal extreme of heat; but if they be suddenly removed from the cold to the heat, or the reverse, they suffer inflammation, mortification, and death. The human subject often, from severe cold, loses sensation in parts of the body; and these are precisely in a similar condition to the parts of plants under the influence of frost. The vital functions are suspended; the blood, like the fluid sap in the plant, ceases to flow; the nerves of sensation refuse to perform their office, either wholly or in part. If such a part of the body *gradually* passes from its dead condition no ill effects will ensue; but if an attempt be made, by the injudicious application of warmth, to promote a sudden reaction, the most serious results may follow. In slight cases chilblains will result; in severe instances of frost-bite, mortification and death. In Arctic regions the fingers, toes, ears, and noses are sometimes frozen; but the experience of the inhabitants of such regions has guided them to the *true* treatment of such injuries—viz., to rub the injured parts with frozen

water pounded, or with snow. This might be quoted in favour of the doctrine — "*similia similibus curantur*," but is quoted to show how experience has proved the benefit of preventing sudden reactions from the effects of cold in the human body. In like manner experience has shown that the life of the plant, or the vitality of its leaves, may be preserved, if, by shielding it from the rays of the sun, a sudden reaction is prevented. For this reason gardeners, before sunrise, take care to cover up the shrubs and crops they wish to protect when an early and unexpected frost has "bitten" them; for they say "the sunshine will do more mischief than the frost."

The temperature of vegetation is above that of the atmosphere in winter, unless the plants are completely frozen, when their life is suspended in some cases, in others destroyed. But this supply of vegetable warmth is sufficient to resist cold to a greater extent than would be supposed; a covering of woollen or of matting being found, in practice, sufficient to preserve plants from injury by very long and severe frosts.

When, nevertheless, a succulent plant, the cells in whose stem and leaves are filled with fluid sap, is so situated as to be fully under the influence of freezing air, a complete death of the plant ensues. I have before explained that when water is cooled to within about ten degrees of the freezing point it ceases to contract, and that, unlike other substances, in passing from a fluid to a solid state it expands considerably. The sap of the plant consists for the most part of water, confined in the passages and cells of the tissue in the leaves and stem; and this fluid, when frozen, expands and lacerates the vital organs so as totally to destroy the life of the plant. If the leaves are placed upon the hand they will be found to be soft and pulpy, as if they had been boiled; so complete has been the destruction of the minute cells of which their tissue was composed.

Another phenomenon associated with the advent of frost was long the theme of superstitious and ignorant wonder. The pedestrian who crosses a meadow in the middle of the day after a frosty night will see, occasionally, the print of footsteps apparently burned into the sod. The grass may be two or three inches in height throughout the meadow, but where these mysterious footsteps have been, the herbage seems singed or seared close to the earth. Before people knew better, and while religion was more completely in the fetters of unreasoning superstition, good folks were wont to point to these footprints as the physical proofs of the existence and personal wanderings of the impersonation of evil. But the "old wives' tale" fell a victim to the progress of science, which discovered how these mysterious footprints could at will be produced by the best of men, if they walked over frozen grass in the early morning, and proved that the supposed Satanic agency was quite unnecessary. The blades of the grass, being completely frozen, were as brittle as the ice which filled and expanded their cells, and consequently snapped off under the pressure of the foot. When the sun rose the greater part of the field was exposed very gradually to its rays, and the grass, therefore, suffered little in general; but the broken blades were only the more completely withered and blackened, because they would be sheltered by the surrounding herbage till the sun was high in the sky, and his beams of considerable power.

The year has now run its course, and the succession of the seasons has been accomplished. The earth has carried us through the immensity of

space, completely round the great luminary on whose beams days and seasons depend, under the guidance of Him "who set the stars in the firmament, and guideth the wanderers of heaven."

Our literary circle of phenomena is also completed; and we lay down our pen as to our readers we sigh—Farewell!

"These, as they change, Almighty Father, these
Are but the varied God. The rolling year
Is full of Thee. Forth in the pleasing spring
Thy beauty walks, thy tenderness and love
Wide flush the fields: the softening air is balm:
Echo the mountains round; the forest smiles;
And every sense, and every heart is joy.
Then comes thy glory in the summer months,
With light and heat refulgent. Then thy sun
Shoots full perfection through the swelling year:
And oft thy voice in dreadful thunder speaks;
And oft at dawn, deep noon, or falling eve,
Thy beauty shines in autumn unconfined,
And spreads a common feast for all that lives."—THOMSON.

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